A MANUAL OF EXPERIMENTS IN ELEMENTARY SCIENCE

CURTIS

TEACHER'S EDITION

CHARLES E. MERRILL COMPANY

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IN

ELEMENTARY SCIENCE

TEACHER'S EDITION

BY

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PREFACE

This Manual of Experiments in Elementary Science consists of a Student's Manual comprising guide outlines, and a Teacher's Manual in which are given full directions and explanations regarding all manipulation, answers to all the questions in the Student's Manual, diagrams, and additional hints and suggestions intended to make the book a complete, convenient mentor.

The outlines are adapted for use with classes in the upper grammar grades, the junior high school, and the first and second years of the high school.

The Manual can be used with any text dealing with beginning science, whether general science, physiography, agriculture, nature study, or physiology; or it can be made the basis of reference or syllabus courses without text, in any of the above subjects. It also correlates with courses in domestic science.

In schools where two or more elementary or second-year courses are offered, the Manual may be used by the same students two successive years.

The Manual can be used in accordance with the demonstration plan, the individual plan, or the partnership or group plan of laboratory course.

The book contains a large number of outlines from which the teacher can select; there are one hundred forty-six fully outlined experiments, besides occasional alternates and many suggested experiments.

The outlines in this Manual follow what is coming to be recognized as the logical method of presenting any experiment in science: Purpose or Object, Materials or Apparatus, Method or Observation, Conclusions or Deductions, Discussion, and Diagram. The experiments, therefore, furnish foundation training in the inductive method, which the student will develop more fully in subsequent laboratory courses.

Great pains have been taken in writing these outlines to insure that the student may deduce *unassisted* the "Conclusions" from the "Purpose" and "Method." It will be noted, therefore, that the "Purpose" is in every case a *definite* statement, the intent of which the student can understand; results are almost certain to be disappointing when a class attempts to perform an experiment of which the purpose is left to be inferred, is stated merely as a word or vague phrase, or is not mentioned at all. Legitimate assistance is given the student in arriving at his "Conclusions" by the guide questions under "Conclusions" in the outlines.

The advantage of having the Manual published in *two books* is paramount. The outline which the student follows should contain no hint of what he is expected to observe; but only the skeleton outline can be free from such hints. It is equally important, moreover, that the manual provided for a teacher's guidance contain an altogether different kind of material from that in the pupil's manual.

Particular effort has been made, in writing this Manual, to make the book entirely adaptable for use as a *demonstration manual,* since a demonstrational course for beginners (first-year and perhaps second-year high school, junior high, and upper grammar grades) has certain striking advantages:

1. When the teacher demonstrates, there is no confusion or loss of time in distributing materials, or in awkward handling of apparatus by students.

2. There is no scattering of effort, such as results from a *novice's* attempts to read a set of printed directions, to perform the operations indicated, and then to refocus his thoughts upon what it all means.

3. The student sees only correct and accurate manipulation; if performing the experiment for himself, he develops an amazing number of false leads. Without conscious effort on his own part, moreover, the beginner under the demonstration plan is helped to acquire proper ideals regarding how laboratory experimentation should be done, since he sees only the teacher's skillful demonstrating.

4. The entire class is working upon the same experiment at the

same time; the instructor's attention is entirely free, therefore, for supervising the reports as the students write them.

5. If a school already has a course in either physics or chemistry, or both, the expense of equipment for a demonstrational course is practically nothing.

6. If a school has no laboratory equipment whatever, the cost of equipping for any first-year laboratory course in which a demonstration manual is used is very little, for one set of apparatus serves any number of students or classes.

In schools where the *partnership or individual laboratory plan* is followed, this Manual, with its skeleton outlines, presents the following unique advantages over the manual which gives more extensive directions for the student:

1. It is sometimes comparatively easy for a student, if he wishes to do so, to write up his reports from a *complete* outline of directions, when he has not done all (or any) of the work. But skeleton outlines furnish him no clue to what is used as apparatus, or what is done with it.

2. Discouragement and diminishing interest are the inevitable results, when a *beginner* is confronted with several pages of unfamiliar printed directions.

3. The skeleton outline tends to make the student observe more carefully, since he knows that he will be expected to write up the "Method" entirely without any guidance from the manual.

4. The report written up from *full* printed directions is frequently more or less a paraphrase of the text, with change of mode and tense. But the skeleton outline compels the student to arrange and express his ideas for himself without assistance, and there are therefore as many *different* reports and — what is much more important — *original* reports, as there are students in the class.

5. No matter how complete are the printed directions in a manual for beginners, the teacher is compelled to direct the work, and to explain and supplement the printed directions. It is easier and requires much less time, therefore, for a *beginner* to follow directions given orally by the instructor, especially if the instructor parallels his directions with demonstrations of his own.

6. It is seldom that the instructor wishes to give to the class

all of any *complete* student outline, and he is therefore required to indicate to the class certain portions to be supplemented or omitted, more or less confusion being the inevitable result. But this objection cannot apply to the skeleton outline.

The author wishes to make very grateful acknowledgments to all those whose cheerful assistance, kindly criticism, and valuable suggestions have made this Manual possible: to Prof. A. R. Sweetser, Head of the Botany Department, University of Oregon; and to his colleagues in the schools of Portland — Miss Emma Griebel, Head of the Physiography Department, Lincoln High School; Elbert Hoskin, Head of the Science Department, Franklin High School; Colton Meek and Miss Emily Johnston, Instructors in Science, Franklin High School; Miss Lucia Macklin, Instructor in Science, Jefferson High School; L. H. Strong, P. A. Getz, and Dr. H. F. Price, Instructors in Science, James John High School; John G. Swensson, M.D.; Mrs. Blanche Thurston, Instructor in English, Franklin High School; and Edith Clements Curtis.

The author wishes also to make grateful acknowledgment of permission to use the somewhat extensive quotations from the following sources: Tarr, *New Physical Geography*, Lynde, *Physics of the Household*, The Macmillan Company; Conn, *Bacteria, Yeasts and Molds in the Home*, and Caldwell and Eikenberry, *Elements of General Science*, Ginn & Co.; Martin, *The Human Body*, and Barber, *First Course in General Science*, Henry Holt & Co.; Hopkins, *Elements of Physical Geography*, and Hessler, *The First Year of Science*, Sanborn & Co.; Pease, *General Science*, and Winslow, *Healthy Living*, Charles E. Merrill Company.

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INTRODUCTION

I. How to Use the Manual

It is generally agreed that every properly constructed experiment consists of a Purpose, Materials or Apparatus, Method or Observation, Conclusions, Discussion, and Diagram. All the outlines in the Student's Manual are constructed to follow this plan as nearly as possible. The Student's Manual, however, is only a series of skeleton outlines which enable the teacher to use any system of laboratory reports he wishes, from the strictly formal write-up to the briefest possible report. The formal write-up is illustrated in the Model Experiment on page xx of the Student's Manual, and careful directions for the student's guidance are given in the Introduction to that book. The first laboratory period may profitably be spent in a recitation on this Model Experiment and the Introduction.

Purpose. — The student should copy the "Purpose" verbatim.

Materials. — The list of materials or apparatus used is supplied by the teacher after he has made his selection, and in the formal write-up is recorded at the place indicated in the student's outline.

Method. — The manipulation indicated is such as to lead directly from "Purpose" to "Conclusion," and it is suggested that all temptation to make more than the fewest possible motions in demonstrating be resisted. A *formal* write-up of the "Method" contains a record of all that was done, and all that was seen by the *student*, but nothing more; it is complete enough to be intelligible throughout to anybody who may read the write-up without seeing the experiment performed. There is apt to be a tendency, on the student's part, to take certain things for granted as being too obvious to require recounting, but such "scamping" of important written work should be discouraged.

CONCLUSIONS. — The conclusions should follow the suggestions contained in the questions under that heading in the STUDENT'S MANUAL, and should be complete statements of the inferences drawn from the Method or demonstration.

DISCUSSION. — The Discussion contains questions closely bearing upon, or suggested by, the demonstrations, and in most cases will give best results if assigned as topics to be looked up in various texts outside of class and reported upon. It is not expected that all the questions in many of the Discussions will be assigned along with the experiment, but the teacher may select from the list such as he thinks valuable and pertinent. If, for instance, the class were studying Experiment 46 in a physiography course, the teacher would probably select one or more questions from Questions 1 to 8 inclusive; but if the course were hygiene, he would probably select from Questions 9 to 14 inclusive. Select the questions which seem best to emphasize the aspects of the subject you wish to emphasize. In the strictly formal write-up, questions are answered fully, so as to indicate clearly what the questions are, without the necessity of referring to the questions themselves. All attempts of the student to make word or phrase answers should be discouraged, as persistence in such attempts is apt to lead to the formation of lazy habits of thought and of statement.

It will be noted that allied experiments are so grouped that a single Discussion at the end of the last experiment in every such series serves for all the outlines in the series. For example, all the Discussion questions dealing with the closely allied soil experiments (Nos. 87 to 92 inclusive) are grouped under the last of this series (No. 92). It will be noted also that a heavy line is used in the text to separate each series of allied experiments from the next. The grouping of experiments is indicated also in the Contents.

Preceding this Introduction (on p. xiii) are lists of experiments suitable for various special courses in elementary science. At the back of the book there is a complete Index, which will help the teacher to locate experiments in a given subject.

DIAGRAM. — The student is required to make outline diagrams of the apparatus whenever the set-up is such as to make its

diagraming worth while, as an aid to fixing ideas, or clearing up all points. A diagram which is not labeled correctly and in considerable detail is likely to prove a waste of time. In the TEACHER'S MANUAL, the diagrams marked *S* are essentially such as the student might be expected to draw; those marked *T* are merely included for the benefit of the teacher, in order to make the manipulation and explanation clear.

It will be found a saving of time to allow the students to diagram the "set-up" as soon as an experiment has been performed, and before they write it up. The apparatus can then be dismembered at once.

II. APPARATUS

The apparatus suggested for the experiments is simple, and can be borrowed, for the most part, from the chemistry and physics departments. Frequent suggestions are given of the types and prices of various suitable pieces of apparatus. In making suggestions regarding apparatus which can be improvised, the author has kept in mind the fact that the teacher usually has little time to make apparatus; hence, the apparatus suggested is simple and, when improvised, will "do the work." The following pieces of apparatus, which may be purchased from the apparatus companies, will be found of very great utility:

Burner, suitable for use with coal gas or gasoline gas, with wing top for glass bending.

1 lb. ¼" soft glass tubing.
2 doz. soft glass test tubes, 6"× ¾".
3 flat bottom, Florence flasks, 4 oz.
3 1-hole rubber stoppers, No. 3.
3 2-hole rubber stoppers, No. 3.
1 triangular file, 4 in.
2 ring stands, each with 2 4-in. rings.
3 burette clamps.
1 square wire screen, 4"× 4".

It is suggested that each student provide himself with a five-cent ruler, marked in centimeters along one edge and in inches along the other and having a protractor upon the back. Figure 1 illustrates the use of the protractor in marking off angles.

A convenient notebook may be made of any standard notebook filler in which one side of every other sheet is ruled for graphs. Students should draw all figures in pencil on these graph pages, and should be encouraged to use the ruler in drawing all straight lines. A serviceable Manila folder in which to place the corrected experiments costs less than five cents.

III. Glass Bending, Pointing, Etc.

Glass tubing may be broken where desired, if a scratch is first made, transversely with the tube, with a three-cornered file; the tube should then be held with the scratch between the hands and away from one. A quick strain outward on the tube will break it off, cleanly.

The end of a glass tube may be sealed (closed) by revolving it just above the inner blue cone of the burner.

Glass tubing may be drawn to a fine point by playing the burner flame (wing top) upon a strip of the tube, rotating it, meanwhile, between one's hands, and, as the glass melts, pulling the tubing apart both ways.

Glass tubing may be bent neatly by heating several inches of the tube over the flame of the wing burner, playing the flame upon the strip between the hands. Rotate the tube to heat it evenly, and when it begins to melt, bend it as desired.

IV. Heating Liquids in Glass Vessels

Liquids may be heated in test tubes and flasks with little danger of breaking the vessels, provided as thin a glass vessel as possible is used, and the vessel is passed back and forth through the flame, or the flame played over the surface of the vessel. Do not allow the flame to play upon one spot. Before applying a flame to a glass vessel, one must be sure that the vessel is perfectly dry on the outside.

V. Profiles

To make a profile for a portion of a topographic map, lay a strip of paper across the map, with the edge along the line where you want

to make the profile (see Fig. A). Make a mark on the paper edge where each contour line appears under the edge of the paper (see

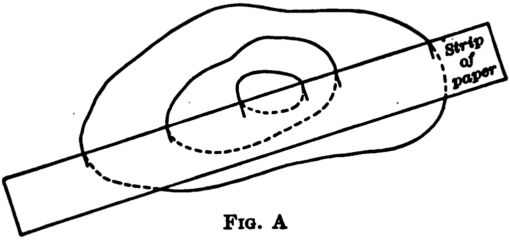

Fig. A

Fig. A). Transfer this strip of paper to the graph paper, and make dots along a line of the graph paper wherever the marks on the

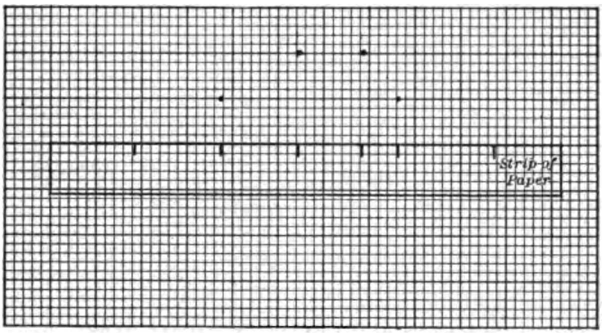

Fig. B

paper strip come (see Fig. B). Let each centimeter on the graph paper represent the contour interval, whatever it may be. On

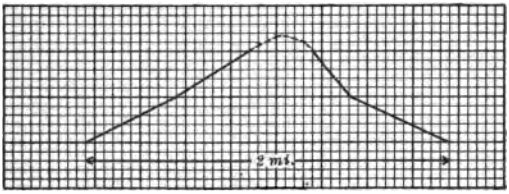

Fig. C

the lines above the dots transferred from the paper strip, mark dots to represent the correct elevation (see Fig. B). Now connect these dots, to complete the profile. Beneath the profile, mark the horizontal scale represented by the profile (see Fig. C). To find this distance, compare the distance between the outer dots on the strip, with the scale on the bottom of the contour map, for the profile will have the same horizontal scale as that of the map.

A profile represents approximately the ruggedness of the path one would have to travel, in following a certain line. The profile of a hill represents how the hill would look from the side, after it had been cut in half from top to bottom. But in nearly every profile, the vertical scale is exaggerated as compared with the horizontal scale, since the latter is taken directly from the topographical map while the former is commonly drawn so that one centimeter represents the contour interval, whatever it may be. In Fig. 82, page 136, for example, the horizontal distance represented is 5.4 mi. while the elevation from the lake level to the top of Glacier Peak is only 1979 ft., or a little more than 1.3 mi. The 5.4 mi., however, cover only about 11.5 cm. measured horizontally, while the 1.3 mi. covers 8 cm. measured vertically. It would be well to explain this distortion to the student when he takes up the study of topographical maps.

EXPERIMENTS IN ELEMENTARY SCIENCE

Experiment No. 1 is the first of a series of five experiments dealing with some of the more important geographical facts. Though it will probably not pay to require the first two of the series to be *written up* as complete reports, it will be found profitable to go over them in class with a complete discussion of the questions. The outlines are so written as to permit a complete write-up, if desired.

No. 1. PARALLELS OF LATITUDE

Materials. — One 6-inch globe; pencil. Better results will be obtained if the students can be provided with 6-inch globes to examine for themselves, individually or in small groups.

Method. — Place the globe upon the desk, but prop it upon books so that the axis is vertical. Rotate it in a counter-clockwise direction. Let the students determine for themselves, as far as possible, the answers to the questions.

Answers. — **1.** Equator.

2. $\frac{1}{4}$ circle or 90° between the poles and the equator.

3. A circle.

4. An infinite number. (Of course this is not *strictly* true since the pencil point is not a mathematical point.)

5. Parallels of latitude.

6. Two cities have the same latitude when they are the same number of degrees from the equator and both above, or both below, the equator.

7. 45° N. 45° N. ——. 56° S.

8. Tropic of Cancer cuts through Formosa, an island east of China. Tropic of Capricorn, through Madagascar, an island east of Africa.

9. 0°. 23½° N. and 23½° S., respectively. 66½° N. and 66½° S., respectively. 90° N. and 90° S., respectively.

10. 53½°. 113½°. 23½°.

No. 2. MERIDIANS OF LONGITUDE

Whether the student is required to write up a complete report of this entire experiment or not, it may be well for him to work out and record for reference in subsequent experiments the answers to Question 3.

Materials. — A 6-inch globe; small ruler with protractor on back for drawing the figure (see p. 3).

Method. — Place the globe in view of the class and allow the students to work out for themselves, as far as possible, the answers to the questions.

Answers. — **1.** Half. Half.

2. Counter-clockwise.

3. 360° 0′ 0″. 15° 0′ 0″. 1° 0′ 0″. 0° 15′ 0″. 0° 1′ 0″. 0° 0′ 15″. (This experiment, of course, is based upon the sidereal day, not the solar day.)

4. Twenty-four.

5. Because of the earth's rotation, the direct rays of the sun cover the distance between two consecutive meridians in one hour.

6. 45° W. 145° E.

No. 3. LONGITUDE AND TIME

Materials. — A 6-inch globe.

Method. — A globe or globes should be where students can examine them, but no manipulation is required, and the students should be able to solve the problem with little difficulty. It may be well to insist upon the student's using the abbreviations

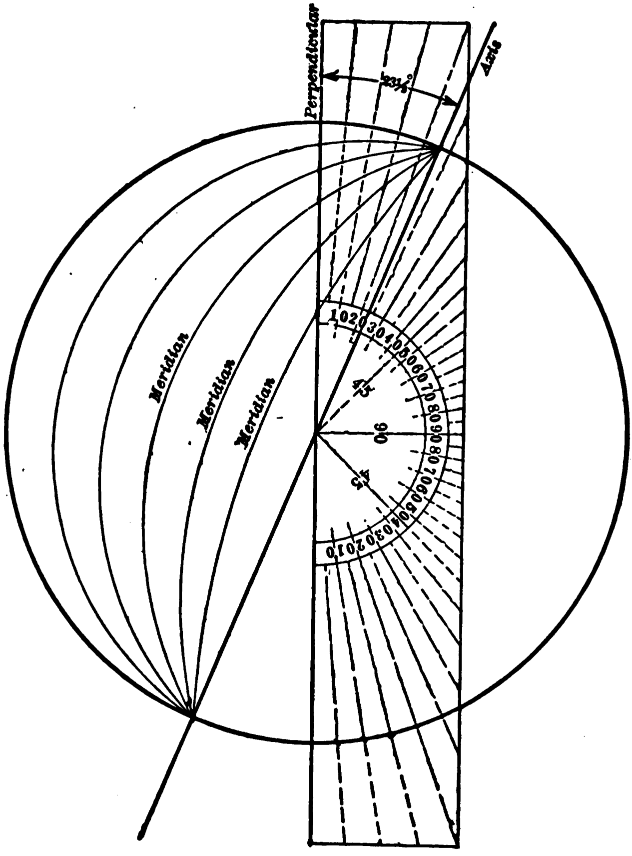

FIG. 1 (S).

In Fig. 1, the solid lines indicate about what the student will draw, while the dotted lines indicate how to place the ruler in order to lay off the 23½° angle from the perpendicular.

NOTE. — The line across the page after certain experiments (as No. 1, above) is used to separate one series of allied experiments from the next (see p. 2). The diagrams marked S are essentially such as the student might be expected to draw; those marked T are merely included for the benefit of the teacher, in order to make the manipulation and explanation clear.

throughout the experiment in order to prevent his confusing min. of time with ′ of longitude, sec. of time with ″ of longitude.

Answers. — **1.** After. Before.

2. A.M., at Philadelphia; P.M., at Rome, Italy.

3. 1 hr. = 15°; 1° = 4 min.; 1 min. = 15′; 1′ = 4 sec.; 1 sec. = 15″; 1″ = $\frac{1}{15}$ sec.

4.

Longitude of Portland is	122° 40′ 0″
Longitude of London is	0° 0′ 0″
Difference	122° 40′ 0″

$122° = 122 \times 4$ min. $= 488$ min. $= 8\frac{8}{60}$ hr. $=$ 8 hr. 8 min.
$40' = 40 \times 4$ sec. $= 160$ sec. $= 2\frac{40}{60}$ min. $=$ 2 min. 40 sec.
8 hr. 10 min. 40 sec.

Sunrise at Portland is, therefore, 8 hr. 10 min. 40 sec. later than at London.

5.

Longitude of Portland is	122° 40′ 0″
Longitude of Philadelphia is	75° 10′ 0″
Difference	47° 30′ 0″

Therefore Portland is 47° 30′ farther west than Philadelphia.

$47° = 47 \times 4$ min. $= 188$ min. $= 3\frac{8}{60}$ hr. $=$ 3 hr. 8 min.
$30' = 30 \times 4$ sec. $= 120$ sec. $=$ 2 min.
3 hr. 10 min.

Sunrise is, therefore, 3 hr. 10 min. later at Portland than at Philadelphia.

6.

2 : 30 P.M. is equivalent to	14 hr. 30 min. 0 sec.
	11 hr. 20 min. 52 sec.
Difference in time between Philadelphia and San Francisco	3 hr. 9 min. 8 sec.

3 hr. = 3 × 15° =	45°
9 min. = 9 × 15′ = 135′ = $2\frac{15}{60}$° =	2° 15′
8 sec. = 8 × 15″ = 120″ =	2′
Difference in longitude between Philadelphia and San Francisco	47° 17′

Longitude of Philadelphia	75° 10′ 0″
Difference in longitude between Philadelphia and San Francisco	47° 17′
Longitude of San Francisco	122° 27′ 0″ W.

7. Since Petrograd is east longitude and Philadelphia west longitude, the two longitudes must be added before the difference in time can be computed.

$$\begin{array}{r} 30^\circ \\ \underline{75^\circ\ 10'} \\ 105^\circ\ 10' \end{array}$$

105°	= 105 × 4 min. = 420 min. =	7 hr. 0 min.	0 sec.
10′	= 10 × 4 sec. =		40 sec.
Difference in time between Philadelphia and Petrograd		7 hr. 0 min.	40 sec.

Since Petrograd time is 7 hr. 40 sec. earlier than Philadelphia time, the clocks in Petrograd will be 7 hr. 0 min. 40 sec. *ahead of* those in Philadelphia, and will therefore show 7 hr. 40 sec. later time.

No. 4.
STANDARD TIME AND INTERNATIONAL DATE LINE

Materials.— Standard Time map and globe for reference; ruler.

Method. — No manipulation required.

Answers. — 1. Your Standard Time will be later than your sun time, provided you live farther west than the central meridian of your time belt, that is, the 75th, 105th, or 120th as the case may be; earlier, if you live east of the central meridian of your time belt. Mean sun time is exact, and varies with each change in longitude, while Standard Time is the same for a large district.

2. Standard Time eliminates the necessity of changing the time every minute or second while traveling east and west, as would have to be done in order to keep the time on trains and steamboats in accordance with the sun time of the places through which they were passing.

3. Ahead. 15° west.

4. The traveler must set his calendar *ahead* one day, because he has lost 24 hr.; *i.e.* those who remained at the starting point have had one more sunset and sunrise than he has had. (For the sake of convenience, imagine that the traveler starts at noon and goes fast enough to keep the sun overhead throughout the whole journey

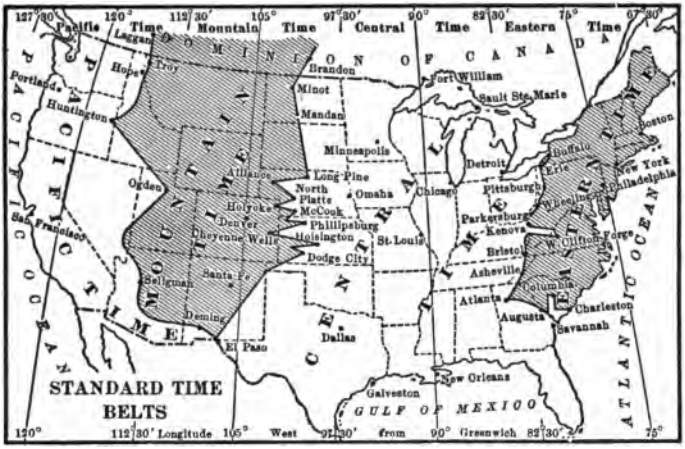

FIG. 2 (T).

around the earth.) If journeying east, the traveler must set his calendar *back* a day, because he has gone to meet the sun, and in a complete circumnavigation has had, therefore, *two* sunrises, while those who remained at home have had but *one*.

5. May 1. April 29.

6. 12:01 P.M. Thursday. 12:01 P.M. Tuesday. 12:01 A.M. Thursday. 12:01 A.M. Tuesday.

The diagrams are a valuable means of clinching the facts illustrated by the experiment, but are not indispensable. If *Wednesday* is written east of the line, *Thursday* should be written west.

No. 5. CAUSE OF SEASONS

Materials. — Six-inch globes; cardboard hoops cut so as just to fit over the globes; corks; penholders and penpoints; compasses.

Method. — The best results will be secured in this experiment if there are enough 6-inch globes to go around the class, or at

least, if there is one globe for every two or three students. Copy on the board the directions for the first, second, third, and fourth positions of the globe, explaining that the directions for the second position should be inserted in place of the line marked A, those for the third position, at the line marked B, for the fourth, at C, and allow the students, unassisted if possible, to work out the answers to the questions. If there is an insufficient number of globes to make this plan practicable, it may perhaps prove more satisfactory to work out the whole experiment as a demonstration, setting up the globe at first position and letting the class work out the answers to questions 1–3; then setting the globe at second position, letting the students work out the answers to questions 4–8; third position, questions 9 and 10; fourth position, questions 11–14. The students will probably need assistance in making their diagrams.

If the formal write-up is used for this experiment, the student should be instructed to insert at A, B, C a full explanation of the manipulation. Be sure that the term *counter-clockwise* is fully understood, in accordance with the explanation in the STUDENT'S MANUAL (p. 2).

Method. — *First position:* By means of the penpoint, stick a penholder vertically into the cork placed upright upon the table or desk. Let the top of this penholder represent the sun. Place the globe upon books or otherwise, so that the vertical rays from the sun (the top of the penholder) fall exactly upon the equator, when the axis points neither toward nor away from the sun, but is inclined to the right, and when the sun (the penholder top) is between the observer and the earth. Call this season *spring*, the date, March 21. Place the hoop vertically about the globe to cut off the part which is illuminated from that which is dark. The illuminated part is called the Circle of Illumination. (In this position the hoop will indicate that the Circle of Illumination passes through both poles.)

Answers. — **1.** Half.

2. Counter-clockwise.

3. *Any place on the earth* has twelve hours of daylight and of darkness, March 21.

Second position (A): Keeping the axis tilted to the right, *revolve* the globe counter-clockwise (as viewed from above) around the sun (the penholder), through 90° or ¼ revolution (see Fig. 3). The axis now inclines *toward* the sun. Call this season *summer* and the date, June 21. Place the hoop to show the Circle of Illumination, June 21. (The hoop will hang vertically

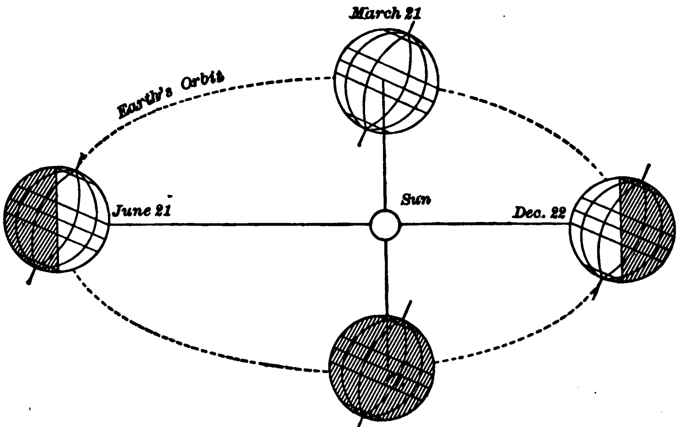

FIG. 3 (S).

from the arctic circle, cutting the equator in the middle, to the antarctic circle.)

Answers.—**4.** Tropic of Cancer.

5. The Tropic of Cancer marks the line where the sun's rays fall vertically farthest *north* of the equator, the date of this occurrence being about June 21.

6. 23½° beyond the north pole. 66½° south of the equator.

7. Twelve of each.

8. At 40° S., nine of daylight, fifteen of darkness; at Philadelphia, fifteen of daylight, nine of darkness.

Third position (B): Revolve the globe another 90° anti-clockwise (counter-clockwise) in its orbit (see Fig. 3), keeping the axis inclined to the right, until the sun's rays again fall ver-

tically upon the equator. The date now represented is September 22. Place the hoop on the globe to show the Circle of Illumination, September 22. (It will again cut through both poles.)

Answers. — **9**. Fall Equinox or Autumnal Equinox.

10. At any point on the earth there will be 12 hr. of daylight and of darkness, September 22.

Fourth position (C): Revolve the globe another 90° in its orbit, until the axis tilts away from the sun (see Fig. 3).

Answers. — **11**. Tropic of Capricorn. The Tropic of Capricorn marks the line where the sun's rays fall vertically farthest *south* of the equator, the date of this occurrence being about December 22. The Tropic of Capricorn is 23½° south of the equator. **12**. Twelve. ——. None of daylight, twenty-four of darkness. Twenty-four of daylight and none of darkness. **13**. Suppose the latitude of your home is 40° N. Since the vertical rays of the sun, June 21, are at 23½° N., your home latitude will be the difference between these latitudes, or 16½° from the vertical rays of the sun. On June 21, the farthest point from the equator where the sun's rays reach at noon, is 23½° beyond the north pole. Since your home at 40° N. is 50° from the pole, and the point farthest illuminated is 23½° beyond the pole, your home will be the sum of these latitudes, or 73½°, from the farthest illuminated point, at noon, June 21.

14. Always twelve of each.

No. 6. ROTATION AND REVOLUTION OF THE MOON

These experiments have been found very effective in assisting the student to learn the distinction between rotation and revolution, the fact that the moon does actually rotate upon its axis, and the cause of the phases of the moon.

Materials. — Globe or ball to represent the earth; round-bottom flask or ball to represent the moon. Dip a crayon into ink and divide the ball or the flask into quarters vertically;

and mark the quarters respectively, *A*, *B*, *C*, and *D*. A round-bottom flask makes a more convenient "moon" than a ball does, because its transparent globe permits a view of all quarters at once, while the neck forms a convenient handle. An old tennis ball, marked similarly and with a hatpin stuck into it to serve as a handle by which to move it around the "earth," will serve. (See Fig. 4.)

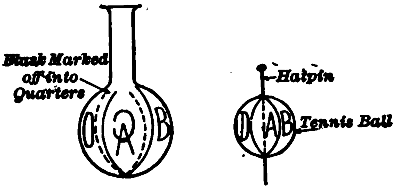

FIG. 4 (T).

Method. — Place the globe or ball representing the earth on the table. Let each student represent the sun. Hold the flask in front of and a little above the globe. Revolve it slowly around the globe counter-clockwise (as viewed from above), always keeping the *AB* half toward the earth. Let each student, as the flask comes opposite him, note some point on it which he can recognize when it next appears as the globe is rotated. Revolve the flask about the globe until every student has determined for himself that the time of rotation and revolution of the moon are the same. It is unnecessary to tell the class that the exact time of the moon's rotation is very close to 27⅓ days, and that the period from one new moon to the next is about 29½ days, because of the earth's progress along its orbit.

No. 7. PHASES OF THE MOON

Materials. — Globe or ball to represent the earth; ball to represent the sun; flask, or old tennis ball marked as in No. 6, to represent the moon.

Method. — Place the ball representing the sun at some distance from the globe, and keep all the class together on the same side of the globe. Hold the flask between the sun and earth, a foot or so from the earth, and a little below, so that the sun, moon, and earth will not be directly in line. Have the *AB*

side toward the earth. Call this position "new moon." Let each student note which would be the illuminated and which the unilluminated quarters of the moon, and let him thoroughly understand that at new moon the moon's surface is *almost* invisible from the earth, because the half toward the earth is unilluminated. Move the moon one quarter revolution counter-clockwise (to the right as you face the globe) to the first quarter, keeping the AB face still toward the globe. (See Fig. 5.) Let the student determine for himself which quarters of the

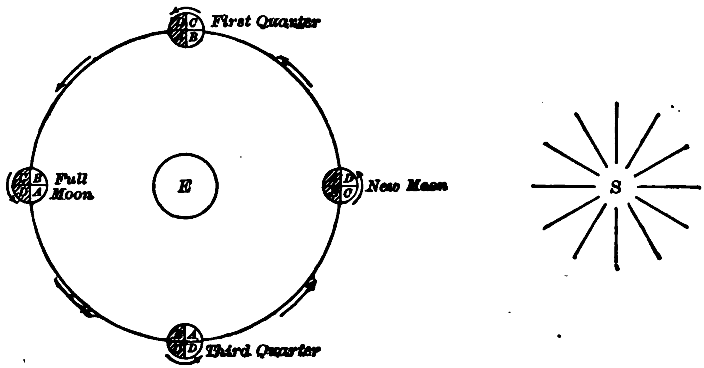

FIG. 5 (S).

moon are illuminated and which of the illuminated quarters would be visible from the earth.

Similarly, with AB always toward the earth, move the moon to a point halfway around, on the opposite side of the earth from the sun, for "full moon," letting the students determine, as before, which are the illuminated and which are the visible quarters. Move the moon likewise to third quarter and then to new moon, letting the student make similar observations. As you revolve the globe from the first phase, new moon, raise it gradually, so that at full moon it is a little above the earth, but as it revolves the rest of the way to new moon, depress it gradually, until at new moon it is in its original position. While this tilt of the moon's orbit greatly exag-

gerates the 5° 8′ angle which the lunar orbit makes with the plane of the earth's orbit, it prevents the student from inferring that there is an eclipse at each new and full moon. It may be well to explain that by "phases" we mean the appearance of the moon at different times during its revolution, and by "first quarter" we mean the first fourth of a revolution, and not the first quarter of the moon itself.

Conclusions. — (The moon's librations in latitude and longitude are here disregarded.)

1. One half.

2. None, because the illuminated half is on the opposite side of the moon from the earth. This is not strictly true, for there is enough reflected light from the earth to make the moon faintly visible; but for the purposes of this experiment and the student's point of view, it is probably better not to mention this fact unless the students ask about it.

3. One fourth, because only half of the illuminated half of the moon is visible at this phase.

4. Half, all the illuminated half being visible.

5. One fourth, for same reason as in Conclusion 3 above.

Answers. — **1.** West. East.

2. Seven.

3. New moon and first quarter; third quarter and new moon. The crescent horns from month to month change the direction of pointing, since a different portion of the lunar disc is illuminated because of the changing relative positions of moon, earth, and sun, as the earth swings around in its orbit.

4. Lunar eclipses can occur only at full moon, whenever the earth is exactly between the sun and the moon; solar eclipses can occur only at new moon. Since the moon's orbit is inclined at an angle of 5° 8′ to the plane of the earth's orbit, there are never possible more than seven eclipses in a year, four solar and three lunar, or five solar and two lunar, and the least possible number of eclipses in a year is two, both solar. The usual number of eclipses in a year is four.

5. When the full moon only partly enters the earth's shadow, a partial lunar eclipse results; when the moon passes almost,

but not exactly, between the earth and the sun, a partial solar eclipse results. When the moon comes exactly between the sun and the earth, and near enough for its shadow to reach the earth, a total solar eclipse results. The moon's orbit is eccentric, that is, the earth is not exactly in the center of the moon's orbit. Sometimes, therefore, when the new moon is exactly between the sun and the earth, it is so far away that its shadow fails to reach the earth, and the sun appears as a bright ring around a dark center, the moon's shadow. The word *annular* comes from the Latin word *annulus*, meaning ring.

6. *Gibbous*, applied to the moon, means convex on both surfaces, and is applied to the moon between first and third quarters. The moon waxes or increases between new moon and full moon; it wanes or diminishes between full moon and new moon.

7. Once.

No. 8. LINEAR METRIC MEASUREMENTS

This and the following experiment are intended to make the metric system more understandable and familiar to the student, through actual work with it. The student should be required to learn the seven prefixes of the metric system and what each means: mill*i* (.001), cent*i* (.01), dec*i* (.1), deka (10), hecto (100), kilo (1000), myria (10,000). Sufficient drill should be given so that the student knows thoroughly the distinction between such units as centimeter (one one hundredth of a meter) and hectometer (one hundred meters); milligram (one thousandth of a gram) and kilogram (one thousand grams), etc. The student should also learn the following abbreviations: mm. (millimeter); cm. (centimeter); dm. (decimeter); m. (meter); Dm. (dekameter); Hm. (hectometer); Km. (kilometer); Mm. (myriameter), and he should learn that the other abbreviations of the system are made similarly: cg. (centigram); dl. (deciliter); etc. As an aid to memorizing the prefixes, the student's attention should be called to the fact that all the prefixes ending in

i denote decimal parts of the unit. The following *equivalents* should be memorized: 1 kilometer (Km.) = .62 mi.; 1 kilogram (Kg. or K.) = 2.2 lb.; 1000 Kg. = 1 metric ton. More satisfactory results will be obtained in this experiment if the student does not know beforehand that 2.54 cm. = 1 in., and 39.37 in. = 1 m. Of course all of these equivalents, except the 1000 Kg. = 1 metric ton, are only very close approximations.

Materials. — Meter-stick or small metric ruler; chalk.

Method. — Let each student make two chalk marks at random at least 5 ft. apart, on the floor or on the laboratory table. Let him *very carefully* measure the distance between the marks, first in inches and *decimals* of an inch, and then in centimeters (cm.) and *decimals* of a *cm.* Let him first compute the number of centimeters in 1 in. and, after reducing the centimeters to meters (m.) by dividing by 100, find the number of inches in 1 m. The student should be able to think out for himself that, to get the first result, he must divide the number of centimeters by the number of inches, and that for the second, he must divide inches by meters or decimal part of a meter, as the case may be. His results should not differ from the correct ones given in line 6 on this page by more than .05 cm. and .12 in. The student should be required to learn the correct number of centimeters in 1 in., and of inches in 1 m.

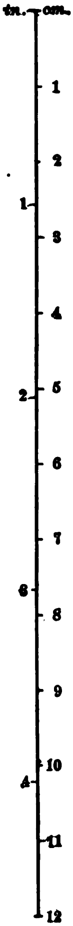

FIG. 6 (S).

FIG. 7 (S).

Answers. — **1.** See line 6 on this page.

2. Insufficient care in measuring, possible inaccuracy in the ruler.

3. 25.4 mm.; .254 dm.; .00254 Dm.; .0000254 Km.; .000254 Hm.; .00000254 Mm.

4. $\frac{\$6.60 \times 2.2 \times 1000}{100} = \$145.20.$

No. 9. VOLUMETRIC METRIC SYSTEM DRILL

The student should learn that in the metric system the prefixes may be applied with the same meanings to units of area, as sq. Dm. (square *deka*meter); volume, as cu. dm. (cubic *deci*meter); and capacity as Hl. (*hecto*liter, or 100 liters), as the prefixes bear when applied to linear units, as Km. (*kilo*meter). Also he should know that in the square table, the multiple is always 100; in the cubic table, always 1000; and in the capacity table, always 10, as in the linear table. Thus, 1 sq. cm. = 100 sq. mm.; 1 c. c. = 1000 cu. mm.; 1 cl. = 10 ml., etc. The student should learn these abbreviations: c. c. (cubic centimeter), ha. (hectare or sq. Hm.).

Since this experiment is intended only as a drill, no heed is paid to the fact that volume units larger than the cubic meter or square units larger than the square kilometer are seldom or never used.

Materials. — Rectangular block; small metric ruler.

Method. — Let the student measure the three dimensions of the block *very* carefully to the nearest millimeter. With this much instruction, he should be able to work out the rest of the Method unassisted.

Conclusions. — **1.** Suppose the area of the face of the block was 164,329 sq. mm. The results would then be: 1643.29 sq. cm., 16.4329 sq. dm., .164329 sq. m., .00164329 sq. Dm., .0000164329 sq. Hm. or ha., .000000164329 sq. Km., .00000000164329 sq. Mm.

2. Suppose the volume of the block was 234,567,890 cu. mm. The results would then be:

234,567.89 c. c.	.00000000023456789 cu. Km.
.00023456789 cu. Dm.	.00000000000023456789 cu. Mm.
234.56789 cu. dm.	.00000023456789 cu. Hm.
.23456789 cu. m.	

Answers. — **1.** 700.

2. 7,000.

3. 7,000,000.

4. 7,000,000.

5. 7,000.

6. 7.

7. In this experiment, the block was assumed to contain 234,567.89 c. c. Its contents as a bin or tank, therefore, would be 234.56789 l., 234,567.89 ml., 2345.6789 dl., 23,456.789 cl., .23456789 Kl., 23.456789 Dl., .023456789 Ml., 2.3456789 Hl.

No. 10. GRAPHIC REPRESENTATION OF FORCES

While very elementary and not strictly demonstrational, the following method for fixing the facts relative to forces and resultants has been found successful, in connection with texts in which a discussion of force and a mention of resultant are given.

It must first be thoroughly understood by the class that anything is a *force* which moves any body, changes the speed or direction in which it is moving, stops it, or has a *tendency* to do any of these things to the body. Numerous examples taken from games, engines, automobiles, etc., can be elicited to clinch these facts. When these ideas are all clear, ask the class to tell you what three things they would have to know before they could obey your command, if you were to give them a rope and tell them to exert a pull of a certain number of pounds in a certain direction upon an object which you have in mind. They will doubtless develop some false leads, but among all the students, somebody will be able to tell you that he must know:

(1) To what the rope is to be attached, *i.e.* the *point of application*.

(2) How much force is to be exerted.

(3) In what direction the pull is to be made.

Materials. — Graph paper; ruler; pencil.

Method. — Explain that in representing forces graphically, the top of the paper or blackboard is considered to be north; the bottom, south; the right side, east; and the left side, west, as on a map. Tell the class that you are going to represent a

force of 10 Kg., acting east, upon a wagon. Make it clear that you are merely going to *represent* the force, and that there will be no attempt to draw a *picture* of the wagon. Make a dot on the board to represent the point of application of the force to the wagon; then, telling the class that you are going to let the length of your crayon represent 1 Kg., draw a straight line 10 crayon lengths long, starting at the dot and drawing to the right. Draw a small arrowhead at the end of the line to indicate the direction, thus:

Explain that by " Scale, 1 mm. = 1 Kg." is meant that, on the graph paper, each student is to let a line 1 mm. long represent 1 Kg. A line 1 cm. long, therefore, will represent 10 Kg.

FIG. 8 (S).

No. 11.
GRAPHIC DETERMINATION OF RESULTANT OF TWO FORCES

It must first be understood that the *resultant* of two forces is the single force which by itself would produce exactly the same effect upon an object that the two forces together produce. Tell the class to study Question 1, in the Discussion, and then to name two forces which are acting upon the ball, and to state in which direction from the point directly opposite the starting point the ball will land. When you have elicited the answer that the forces are the wind and the force exerted by the thrower, and that the ball will fall at a point east of the direct north-and-south line across the street,

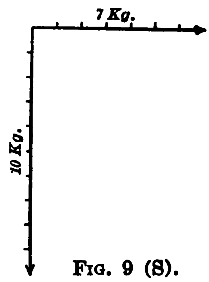

FIG. 9 (S).

diagram the two forces on the board from a single point representing the ball, using a scale of 1 dm. to represent 1 Kg.

Then, to find the resultant, complete the rectangle formed by these forces as sides and draw the diagonal of this rectangle to represent the resultant. This diagonal will be 12.2 dm. long, and since 1 dm. represents 1 Kg., the resultant of the two forces would be 12.2 Kg., and its direction, as indicated by the diagram, a little east of south.

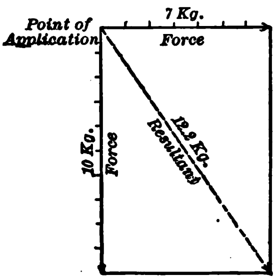

FIG. 10 (S).

The ball would not, of course, follow the straight diagonal path but would change its direction gradually because of its inertia, and it would also tend to "curve" because of the unavoidable whirl imparted to it by the thrower. Unless questions are raised by the class at this point, it is unnecessary to mention the above facts. Students will probably attempt to solve all resultant problems by the rectangle method: "the square of the hypotenuse of a right triangle equals the sum of the squares of the sides," but this method holds only for rectangles. The graph method, however, as explained above, lends itself admirably to fairly accurate solutions of all two-force resultant problems.

Answers. — 1. See explanation above.

2. Since both forces are acting in the same direction, the resultant, or the single force which would produce the same effect

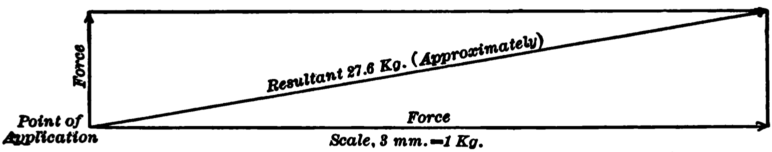

FIG. 11.

that the two forces produce, would be the sum of the two forces, or 24 Kg., and the direction would be that of both forces.

3. Since the forces were exerted in opposite directions, the resultant would be the *difference* of the two forces, or 8 Kg.,

and its direction would be that in which the brother pulls, *i.e.* in the opposite direction from that of the resultant in the second problem.

LEVERS

The following three experiments are intended merely to enable the student to grasp the *principles* involved in the three classes of levers. Very rough apparatus will accomplish this purpose efficiently. All questions dealing with the mathematical laws of levers, such as the Principle of Moments, are left to be solved with the help of more accurate apparatus in a regular physics course. To avoid possible confusion to the student, the force is exerted at a point to the right of the fulcrum throughout the three experiments.

No. 12. LEVER OF THE FIRST CLASS

Materials. — A triangular-shaped block, about 2 in. long, made by sawing a rectangular block of wood lengthwise diagonally, for a fulcrum; half a lath, for a lever; two half bricks, or any two similar objects about the same size, fairly bulky

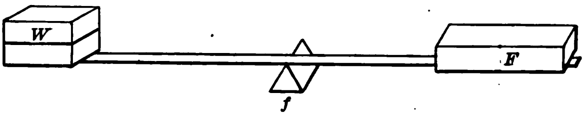

FIG. 12 (S).

and having flat surfaces, for W (whole bricks are too heavy for the lath); a much larger brickbat, or whole brick; an ordinary laboratory spring balance with which to register F.

Method. — Rest the middle of the lath on the apex of the block. On the left side, place one of the half bricks and make the whole brick placed on the right side balance the half brick. This need not be done very carefully. When this balancing is accomplished, place the second half brick upon the first one

and slide the whole brick away from the fulcrum till a rough balance is again attained. (See Fig. 12.) Since the "given acting force" (F) (the whole brick) remains unchanged, the student will readily see that by "using a lever of the first class one can lift a heavier weight with a given force when the force is applied at a point farther from the balancing point."

No. 13. LEVER OF THE SECOND CLASS

Materials. — Same as in No. 12.

Method. — Supporting the lath with the left end across the block and the right end resting upon the hook of the balance, the scale and indicator of which are toward the class, place one of the half bricks on the lath near the fulcrum, and slowly slide it along the lath toward and then away from the balance, call-

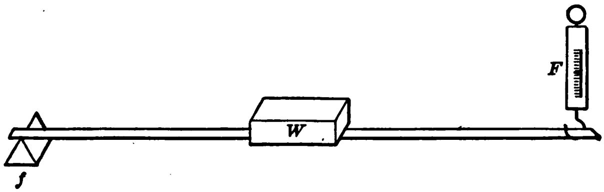

FIG. 13 (S).

ing attention to the indicator meanwhile. (See Fig. 13.) By the obvious increase registered by the balance, of the force required to lift the same weight as it is shifted farther from the fulcrum, the class will readily see that, using a lever of the second class, one should place the weight as *near* the fulcrum as possible, in order to lift a given weight with the least possible effort.

No. 14. LEVER OF THE THIRD CLASS

Materials. — Same as in No. 12.

Method. — Place the left end of the lath under the edge of the table. On the right end place a half brick, and support

the lath by placing the hook of the balance under the lath about the middle. (See Fig. 14.) Shift the position of the balance along the lath, calling attention to the indicator meanwhile, until it is obvious to the whole class that in a third-class lever, less effort or force is required to lift a given weight when

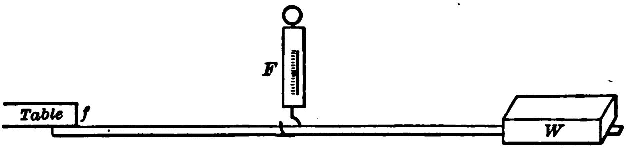

FIG. 14 (S).

the force is applied at a point as *far* from the *fulcrum* and as *near* the *weight* as possible.

Answers. — **1.** Sliding the fulcrum toward the weight is equivalent to grasping the lever at a point farther from the fulcrum.

2. (*a*) Third: the fish is *W*, *F* being applied between the fish and the point (*f*) where the pole touches the hand;

(*b*) second: *W* is between *F* (the hands), and *f*, the axle of the wheel;

(*c*) first: water is *W*, rowlock is *f*, hands, *F*;

(*d*) double lever of second: pivot is *f*, nut, *W*, the hands, *F*;

(*e*) third: meat is *W*, and *F* is applied between *W* and the point where knife rests against the hand, *f*;

(*f*) first: each child is *F* when he lifts the other child, *W*, balancing point, *f*, being between;

(*g*) double lever of first: cloth is *W*, pivot, *f*, and hands, *F*.

3. First, if the crowbar is pivoted over a stone, and the bar pushed down; second, if the point of the crowbar is inserted as far under the log as possible, and the handle of the bar raised.

4. Farther from the hinge; gate is a first-class lever, in which the child is *F*, the lower hinge, *f*, and the upper hinge (which would be first to give way), *W*.

5. Third, because the distance through which *F* acts is always less than that through which *W* acts.

No. 15. WORK (PULLEYS)

In this experiment, only the bare fundamentals are given; all of the more advanced applications are left to be taken up later in a regular physics course.

Materials. — If one has access to a physics laboratory, a support stand, right-angle clamp, extra rod and hook collar make an excellent set-up for this experiment. But in case such a set-up is not available, a large nail fastened to a board by staples, with the end projecting, makes a good support for the pulley. But in either case, the following are needed: single pulley; cord; spring balance; two meter sticks or yardsticks; known weight, as 1 Kg. (a smaller weight is apt to give unsatisfactory results).

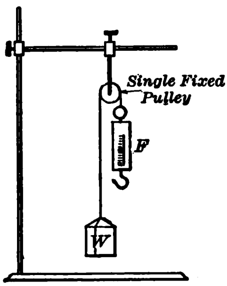

FIG. 15 (S).

Method. — When the apparatus is set up as in Fig. 15, let a student hold one meter-stick vertically beside *W*, while another holds the second meter-stick beside the balance. The reading of the balance is the acting force (*F*) and the Kg. weight, the resisting force (*W*). The balance is suspended from the ring instead of by the hook, in order to eliminate from the computation the weight of the balance. Let part of the class note how many cm. *W* rises, as *F* is lowered through any convenient distance, say 50 cm. Let the lowering be uniform; avoid jerks. Take the reading of *F* only while *F* is descending; attempts to eliminate the friction by averaging *F* when it is rising and falling uniformly are not only needless, since, in an actual machine, friction can never be entirely eliminated, but are also apt to be unsatisfactory because of the imperfections in the apparatus. Moreover, so complicated a demonstration is sure to produce confusion in the minds of beginners. The actual work done is *F* times the distance through which the balance is lowered; the useful work accomplished is *W*

times the distance the weight is raised. Work is usually expressed in g. cm., or in ft. lb.

No. 16. EFFICIENCY

Materials. — Data from No. 15.

Method. — Find the efficiency of any machine by dividing the useful work accomplished by the machine, by the actual work put into it.

No. 17. MECHANICAL ADVANTAGE

Materials. — Same as in No. 15.

Method. — The resistance or weight (W) divided by the effort or force (F) is the mechanical advantage of any machine.

Set up the movable pulley as in Fig. 16. Let students take the reading of F while it is being raised slowly and steadily. It may be well to explain that in any system of *pulleys* the mechanical advantage would always be equal to the number of strands of cord actually *shortened,* provided there were *no* friction, but since there is *always* friction, this ideal ratio never works out in practice. For W, take the weight of the pulley and add it to the weight attached to the pulley.

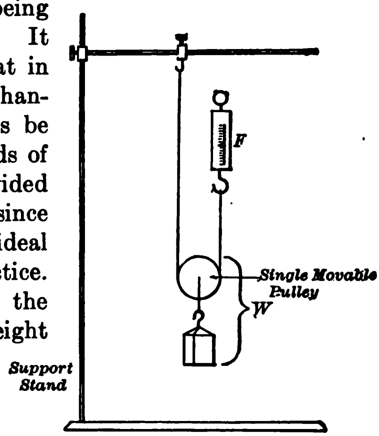

Fig. 16 (S).

Answers. — **1.** Merely a change of direction in which the force can be exerted.

2. Because of friction. No machine has 100 per cent efficiency, because friction can never be entirely eliminated.

3. Lever, pulley, wheel and axle or windlass, inclined plane, wedge, and screw. But these six machines can be resolved

into two classes: the lever and the inclined plane. The pulley is merely a revolving lever of the first class in which both arms are equal, and the windlass is a revolving lever of the first class, in which the arms are unequal; a wedge is a double inclined plane in which the bases are together and the two inclines meet at a point, and a screw is a spiral inclined plane.

No. 18. VOLUME OF AN INSOLUBLE SOLID

Materials. — Any irregular solid body such as a glass stopper, piece of lead or iron, stone, etc., around which a thread may be tied; graduate cylinder, filled to a given mark with water. A weight may be used more conveniently than the stopper, and will save time in No. 19, since it will not need to be weighed.

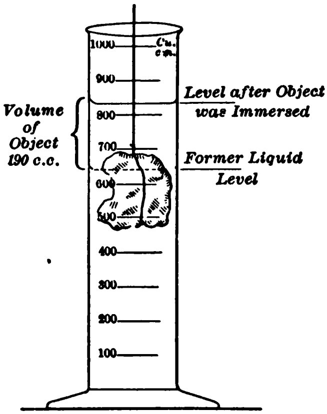

FIG. 17 (S).

Method. — Note the level of water in the graduate, then lower the stopper into the water and again read the level. (See Fig. 17.) In each case read the level at the bottom of the meniscus, or curve of the liquid. Since the water and the stopper cannot both occupy the same space at the same time, the difference in water levels indicates the volume of the stopper in cubic centimeters (c. c.).

No. 19. DENSITY OF AN INSOLUBLE SOLID

Since density is rapidly displacing specific gravity in scientific works, a separate experiment on specific gravity is not included in this book, but an opportunity to bring out the distinction

between density and specific gravity is given in the Discussion at the end of No. 20.

The density of a substance is the number of *grams* which *1 c. c.* of the substance *weighs*, or the number of *pounds* which *1 cu. ft.* of the substance *weighs*. It is never correct to say that one substance is *heavier* than another, but what is usually meant by such a statement is that one substance is *heavier, volume for volume*, or has a greater *specific gravity*, or is *denser* than the other substance.

Materials. — The same object used in No. 18; balances or scales.

Method. — Dry the object carefully, then weigh it. The density will be found by dividing the weight in grams by the volume in c. c., found in No. 18. The density of glass is 2.5 to 2.6 g. per c. c.; of lead, 11.3 to 11.4 g. per c. c.; of cast iron, 7.2 to 7.4 g. per c. c.

No. 20. DENSITY OF A LIQUID

Materials. — Water, gasoline, kerosene, brine, or any other liquid the density of which you want to find; balances; glass-stoppered bottle, preferably, or any vessel which you can fill accurately to a certain level. Water level can be taken more accurately in a narrow-necked bottle or flask, than in a wide one. A mark can be made on the outside of the bottle with a three-cornered file or carborundum crystal, to indicate the level of liquid.

CAUTION: *If gasoline or kerosene is used, allow no flame near it.*

Method. — Weigh the empty bottle or vessel. Fill it with the liquid exactly to the mark, weigh it again, dry and fill it with water, and again weigh it. The difference between the weight in grams of the empty bottle and the bottle filled with water is the *volume* of the bottle, for 1 c. c. of water may be considered to weigh 1 g. The difference between the *weight* of the empty bottle and of the bottle filled with the liquid is the *weight* of the liquid, the *volume* of which is the same as the volume of the bottle. The density of the liquid is, then, the weight

divided by the volume. The density of gasoline is .7 g. per c. c.; of kerosene, .8 g. per c. c.

Answers. — **1.** The density of the metal composing the ball is the weight of the ball divided by $\frac{1}{6}\pi$ times the cube of the diameter.

2. A stone dropped into the ocean would sink to the bottom, because the difference between the density of the stone and that of the water remains about the same at the bottom of the ocean as at the top.

3. The berries are less dense than the liquid in which they are preserved.

4. Warm air is less dense than cool air.

5. Density is the weight in grams of 1 c. c., or the weight in pounds of 1 cu. ft., of any substance; the specific gravity is the *weight of any volume* of a solid or liquid compared with, or divided by, the *weight of an equal volume of water*, or it is the density of a solid or liquid compared with, or divided by, the density of water. The density of aluminum is, for example, 2.58 *g. per c. c.*; the specific gravity of aluminum is 2.58, which is equivalent to saying that *any* bulk of aluminum weighs 2.58 *times* as much as an *equal bulk* of water. In the case of gases, the standard of comparison is not water but hydrogen or air, but unless necessity arises, it may be better not to state this fact to elementary science classes.

No. 21. EFFECT OF HEATING AND COOLING A SOLID

Materials. — Metal ball and ring which can be obtained from the apparatus companies at small cost; burner; vessel of *cold* water.

Method. — First show that the ball will just pass through the ring; heat the ball in the flame and show that it no longer will pass through the ring, then plunge it into the cold water. The cooled, and hence contracted, ball will again pass through the ring. The steam which rises from the metal as it heats is due to the evaporation of the water formed by the union of hydrogen in the gas flame with oxygen of the air.

No. 22.
EFFECT OF HEATING AND COOLING A LIQUID; PRINCIPLE OF THE THERMOMETER

Materials. — Florence flask or hard glass test tube fitted with one-hole rubber stopper and glass tube several inches long; support stand; burner; cold water colored with a few drops of ink or litmus.

Method. — Fill the test tube full of the water, insert the stopper and tube, pressing the stopper down until the liquid has risen a short distance in the tube. Without allowing the liquid in the test tube to boil, heat it until it has expanded sufficiently to approach the top of the tube. Then allow the water to cool again and contract.

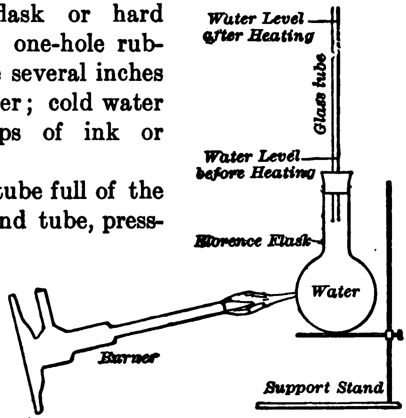

FIG. 18 (S).

No. 23. EFFECT OF HEATING AND COOLING A GAS

Materials. — Same as in No. 22, without the colored water, and with the addition of a beaker or tumbler of water.

Method. — Invert the test tube as in Fig. 19. Apply heat to the test tube. The bubbles which escape from the end of the tube into the water are caused by the expansion of the air in the test tube. Do not heat the test tube too much; remove the flame and call attention to the movement of liquid in the tube, toward the test tube. There is DANGER in letting the water bubble into the test tube itself, for its presence there quickly cools the air in the test tube. The resulting contraction of the air causes a more rapid flow of water into the test tube; if the cold water strikes the hot glass then, it is converted into steam and at the same time breaks the tube, causing an ex-

plosion. It is incorrect to say that the water rises into the test tube: when the air in the test tube cools and contracts, a partial vacuum or reduced pressure is created in the test tube, the result being that the greater air pressure outside presses down on the water and *forces* or *pushes* it up into the test tube.

Answers. — 1. Heating a body increases the volume, and cooling a body diminishes the volume, with the result that in the former case the density is decreased and in the latter, increased, for the weight remains the same in both cases.

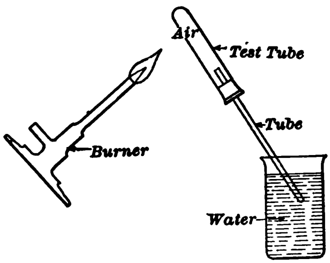

FIG. 19 (S).

2. Summer. Heat expands the wires and causes them to sag.

3. As the milk heats, it expands and overflows the bottle.

4. There is the same quantity of mercury in the thermometer at all temperatures, but the apparent increase is due to expansion, or, in other words, the warmer a body is, the farther apart are its molecules.

5. Since the temperature of a body is measured by the average speed of its molecules, the hotter a body is, the faster its molecules are moving; and hence the farther apart the molecules are knocked by collision with one another. The reverse is true in the case of a cooled body.

6. Galileo's thermometer was essentially the same as the apparatus in Fig. 19 (without, of course, the burner), hence the level of liquid in the neck of the flask indicated the expansion or contraction of the air in the flask, due to temperature changes. It was inaccurate because it responded also to changes in the pressure of the atmosphere.

7. Sudden heating or cooling of the exterior of rocks produces sudden expansion or contraction, as the case may be, the result being a fracturing of the rock. Expansion and contraction are important weathering agents. (See No. 102, Discussion.)

No. 24. PURIFICATION OF WATER BY FILTERING

Materials. — Funnel; filter paper; funnel stand or other support; tumbler or beaker of dirty water; clean, empty tumbler or beaker. A new thin blotter, preferably without printing, will serve instead of the filter paper, funnel, and stand.

Method. — Fold the filter paper into fourths by folding it over twice. Fit it into the funnel with three thicknesses on one side and one on the other; moisten it with a few drops of clean water so that it will fit into the funnel. Place the funnel in the support over the clean tumbler. Pour the dirty water through the filter paper. The class will note that the water which comes through the paper (the filtrate) is clear, and that the mud and solid impurities (the sediment) are left on the paper. It is advisable to use the term "filtrate," as it will prove an important addition to the student's chemistry vocabulary. If the blotter is used, fold it in half, and then once again diagonally on each side, so as to form a cup-shaped receptacle into which to pour the dirty water. Hold this blotter cup in your hand above the clean tumbler.

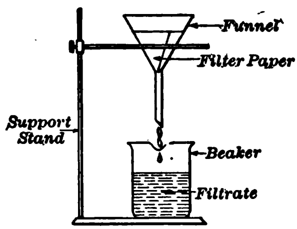

FIG. 20 (S).

No. 25. PURIFICATION OF WATER BY DISTILLATION

Materials. — Burner; support stand; flask of muddy water; Liebig condenser. If no Liebig condenser is available, a serviceable condenser can be easily improvised in one of the following ways:

I. Into each end of the neck of a Florence flask, the bottom of which has been broken off, fit a two-hole rubber stopper. Through the neck and both corks, fit a glass tube, and fit a

short piece of glass tubing into each of the other holes in the corks. (See Fig. 21.) Connect the flask to one end of the long tube, and place the tumbler at the other end. Connect the lower short tube to the faucet by means of rubber tubing, and the outtake tube into the sink, to the upper short tube through the stopper. (See Fig. 21.)

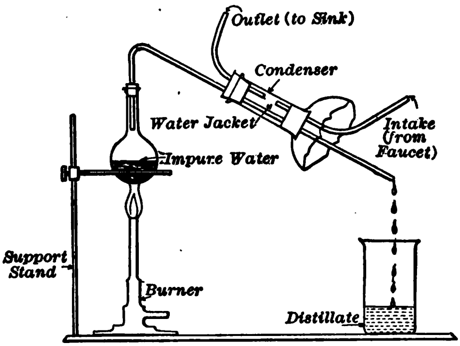

FIG. 21 (S).

II. A large straight glass tube, such as is used for resonance and liquid pressure experiments in physics, may be substituted for the flask-neck used above.

If the laboratory is not equipped with faucets so that running water is available, either of the following devices may be substituted, though the condensation of the vapor is necessarily much slower.

1. The muddy water may be placed in a retort, and a strip of cloth, previously moistened, wound spirally about the neck of the retort, but with both ends hanging. (See Fig. 22.) Allow cold water to drip upon the cloth through a small hole punched in the bottom of a can or bucket. Place a pan or dish below the cloth to catch the water,

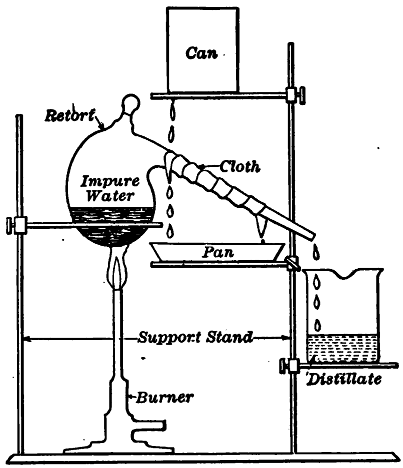

FIG. 22 (S).

and have ready another cloth, slightly moistened, to wipe off any water which may tend to continue down the retort tube into the tumbler. (See Fig. 22.)

2. If you have no retort, use a flask as in (I) above, and instead of the condenser, connect the tube from the flask directly to a long glass tube, around which the moistened cloth is to be wound as directed above. (See Fig. 23.)

Corks *may* be used in place of the rubber stoppers, but they are less satisfactory, and after they are fitted into the condenser, it will be necessary to pour melted paraffin over them to render all the fittings tight. Use as little rubber tubing as possible between the flask and the condenser, as glass tubing condenses the vapor more efficiently. Do not allow the muddy water to boil so violently that it spatters over into the tube leading to the condenser.

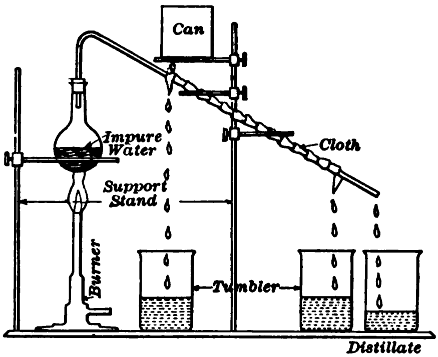

FIG. 23 (S).

Answers. — 1. Substances in solution and bacteria. The latter are so small as to pass through the pores of the ordinary filter, which is not specially constructed.

2. Sunlight and the oxygen of the air, including the oxygen which exists in the pores of the soil, kill many of the bacteria. Moreover, certain kinds of bacteria exist in porous soil, which — by consuming the available food as well as by excreting injurious waste material — indirectly destroy some of the harmful bacteria. If dirty water is thrown too near a water supply, it is apt to seep into the water supply without being entirely purified, and carry with it many harmful bacteria.

3. River water is first pumped into settling tanks, then mixed with a small amount of alum and allowed to filter through

sand beds, the alum forming a coating on the top of the sand which catches most of the bacteria. A little chloride of lime is added to the water as a disinfectant before the water is admitted to the mains. This is essentially the Jewel System.

4. Distillation, because the bacteria are destroyed by the boiling. Also, distillation removes all dissolved substances from the water.

5. By distilling sea water, that is, by boiling it and subsequently condensing the vapor.

6. The water jacket cools the vapor in the inner tube, thus causing a more rapid condensation of the vapor.

7. Water vapor particles or molecules are evaporated or freed by the sun's heat from the surface of lakes, ponds, etc., and from the soil where the water rises to the surface by capillarity. These particles, or molecules, because of their own motion and the action of winds, are scattered or diffused through the air. This moisture-laden air is subsequently cooled by coming into contact with cold air currents from the north or from higher altitudes and, to some extent also, by radiation; the moisture is therefore condensed and formed into clouds. Precipitation follows when the condensed moisture drops are sufficiently heavy to fall, provided the air between these clouds and the earth is sufficiently saturated that the drops of rain are not re-evaporated in their fall to the earth.

8. The sun corresponds to the burner; lakes and other bodies of water, to the flask of dirty water; cold currents of air, to the water jacket; clouds where the vapor is first condensed upon dust particles, to the condensing tube; rain, snow, etc., to the water which collects in the tumbler.

9. Through sand, because it is more porous and less compact than clay.

No. 26. BOILING POINT ON A THERMOMETER

This and the following experiment will prove interesting and valuable to a class capable of doing work somewhat above the elementary qualitative experiments. It will be found

advisable to work this experiment through with the class, making full and adequate explanations. The experiment should teach that an accurate thermometer does not necessarily need to register 100° C. or 212° F. always, for the variations in barometric pressure from day to day will make a difference of several tenths of a degree in the boiling point.

Materials. — Burner; stand; Florence or Erlenmeyer flask partly full of water; thermometer; barometer.

Method. — Light the burner under the flask placed upon the support stand. When the water comes to a boil, dip the thermometer bulb into the water and then hold it just above the surface, in the steam. (See Fig. 24.) It will perhaps be noted that for an instant the mercury level falls a little, before it begins to rise. The reason is that the expansion of the glass tube makes the bore larger, and the poor heat conductivity of the glass prevents the immediate expansion of the mercury.

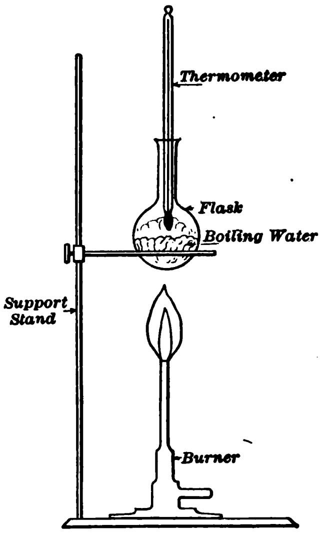

FIG. 24 (S).

Let the students take the temperature to the nearest tenth degree. Since an accurate thermometer registers 100° C. and 212° F. at boiling point only when the barometer reads 76 cm. or 29.9 in., respectively, a difference of 2.7 cm. or 1.06 in. in the barometric pressure will make a difference of about 1° C. or 1.8° F. But this holds true *only* for temperatures *near 100° C. or 212° F.; i.e.* the rise in boiling point does not increase proportionally with the rise in pressure. Also a rise in altitude of about 967 ft. lowers the boiling point 1° C., and 537 ft. lowers the boiling point 1° F. Take the barometer reading. Figure then what the boiling point should be at your altitude above

sea level at the maximum water vapor pressure, which at sea level is 76 cm. or 29.9 in. Determine the difference between this reading and the barometric reading, and from the data above, determine what the boiling point should be for that day upon which you performed the experiment. Of course this last calculation will be only approximate for high altitudes.

No. 27. FREEZING POINT ON A THERMOMETER

Materials. — Tumbler or beaker of pulverized ice or snow; thermometer.

Method. — Pack the snow or ice into the tumbler and pour in enough water to fill the crevices between the pieces of ice. Allow sufficient time for the water to reach the temperature of the ice, which is 0° C. or 32° F. Pack the bulb of the thermometer in the ice or snow, but not so deep that you cannot read the thermometer to the nearest tenth degree. The thermometer should register 0° C. or 32° F.

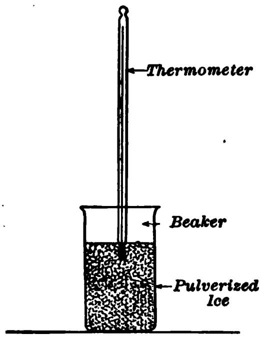

FIG. 25 (S).

Answers. — **1.** Above 100° C., because the barometric pressure is normally greater than 76 cm. or 29.9 in.

2. The boiling point is so low that, though the water boils, it is not hot enough to cook the potatoes rapidly.

3. Increasing the amount of gas flame or wood fire under a kettle does not cause the contents to cook faster; it causes the kettle to boil dry faster, because the more heat there is, the more rapidly the water is converted into steam.

No. 28. SOLUTIONS (SOLIDS IN WATER)

Materials. — Borax (Sodium tetraborate, $Na_2B_4O_7$) or potassium dichromate ($K_2Cr_2O_7$); test tube; burner; water.

Method. — Fill the test tube half full of cold water and add *powdered* borax or *pulverized* $K_2Cr_2O_7$, shaking the test tube vigorously until as much of the solid is dissolved as will dissolve. Some will still remain in the bottom of the tube. The $K_2Cr_2O_7$ may first be pulverized in a mortar, or may be placed between strong cloth layers and pounded into a powder. The finer the solute, the more readily it will dissolve. Explain to the class that *solute* is the substance which dissolves in the *solvent* to form the *solution.* Also explain that since as much of the solute as will dissolve has dissolved, the solution is a *saturated solution.* Now heat the contents of the test tube by passing it back and forth through the flame, holding it well above the inner blue cone. As the contents become warm, shake the tube until the rest of the solute has dissolved. The students should be able, unassisted, to infer that the hot solvent dissolves the *greater* quantity of *solid* solute.

No. 29. SOLUTION (AIR IN WATER)

Materials. — Cold water, preferably ice water; tumbler or other glass vessel.

Method. — Place the ice water in the glass vessel, and call attention to the fact that there are no bubbles along the inside of the vessel. Leave the vessel in a warm place, but do not heat it, as the students may get the idea that the bubbles of air which appear on the inside surface of the vessel are steam. At the end of the period call attention to the bubbles, emphasizing the fact that the water has been warmed somewhat by being in the warm room. The students will be able, unassisted, to infer that a liquid solvent will dissolve or hold in solution a *smaller* quantity of *gaseous* solute when warm than when

cold, which is just the opposite of the case of the solid solute and liquid solvent, as illustrated in No. 28.

No. 30.
CONDITIONS UNDER WHICH CRYSTALS FORM

Materials. — I. $Na_2B_4O_7$ (borax) or $K_2Cr_2O_7$ (potassium dichromate); two test tubes; burner; funnel; filter paper or blotter. II. Powdered alum, salt (NaCl), and copper sulphate ($CuSO_4$, blue vitriol); two tumblers; thread.

Methods. — I. Heat half a test tube full of water to boiling temperature, as explained in No. 28. If it gets too hot to hold, make a holder as explained in the Method of No. 34. When the water is boiling, add either the powdered borax or the pulverized $K_2Cr_2O_7$, as explained in No. 28, being sure to add more than will dissolve in the boiling water. Filter the saturated solution into the other test tube, by the Method explained in No. 24. Dip the bottom of the test tube containing the filtrate into cold water, or allow water to play over it so as to cool the solution as rapidly as possible. The crystals will separate out quickly, for the cold solvent cannot hold so much solid solute in solution. The class will be able to infer that crystals are formed when a saturated solution is cooled.

II. It will take from one to several days to complete this experiment. Dissolve a considerable quantity of powdered alum and powdered copper sulphate in hot water, but do not try to saturate the solvent. Similarly, dissolve the salt in either hot or cold water. Place a thin strip of pasteboard across the top of each of the two tumblers containing, respectively, the copper sulphate and the alum, and hang some pieces of thread over this paper strip, so that the ends extend into the solutions. Set the three tumblers aside to evaporate. Inside of a day or so small crystals of salt will be seen floating upon the surface of the salt solution, while the copper sulphate and alum crystals will deposit upon the strings. Do

not attempt to explain the forms of the crystals produced as the crystals are not apt to be perfect. The class will be able to infer that as the solutions evaporate, they are able to hold in solution less of the solute, and that therefore a second condition under which crystals separate out of a solution is evaporation.

Answers. — **1.** Solvent in each case, water; solute (No. 28) borax, and potassium dichromate; (No. 29) air; (No. 30) I, borax, or potassium dichromate; II, salt, alum, and copper sulphate.

2. Taste, color (the solution usually assumes the taste and color of the solute), higher boiling point, lower freezing point, greater density.

3. As the water evaporates, the salt is left behind in the solution, or in solid form on the shore.

4. Water draining from the land always carries some salt in solution. If this water empties into a lake which has no outlet, the water evaporates from the lake, leaving the salt behind.

5. Salt lakes, or more usually arms of the ocean, cut off by a rising of the land, have evaporated.

6. Each drop of water lighting upon stone dissolves a part of it.

7. The O is in solution in the cold water. When water is boiled, almost all the air is expelled.

8. Water is the best solvent known and dissolves different minerals, such as salt, "alkali" (sodium carbonate, frequently), calcium and magnesium sulphates or carbonates, air, etc.

9. Any spring containing an extraordinary amount of some common mineral in solution, as for instance iron or lime carbonate, sulphureted hydrogen, or compounds of lithium.

10. See Answer 6, No. 77.

11. See Answer 1, No. 84.

12. Chemical. New substances result, hydrogen and zinc chloride, which can be separated from the solvent. Physical.

13. It may be best not to give this question, unless your text discusses minerals in considerable detail. Some common crystals are diamond, sulphur, quartz, etc. They are too numerous to require enumeration.

14. In the experiment, crystals were formed directly by cooling and evaporating solutions. Crystals may also be made by freezing solutions and liquids, as in the case of snow and ice (the latter is composed of small crystals closely packed together).

No. 31. CONVECTION IN AIR

Materials. — Convection box with student lamp chimneys; candle end; touch paper. A convection box with or without a glass front can be bought from the apparatus companies at small cost, or one can be improvised out of a pasteboard shoe

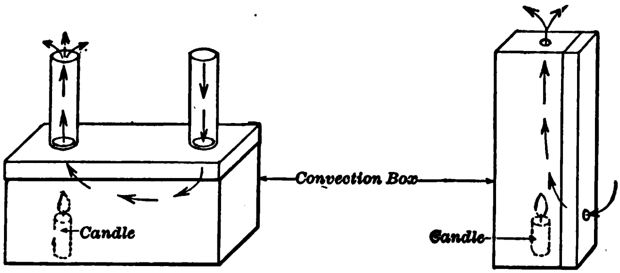

FIG. 26 (S). FIG. 27 (S).

box and a couple of pasteboard cylinders about 6 in. long, such as those in which documents are sent through the mail. Make two holes a little smaller than the diameter of the cylinders, one at each end of the box cover. (See Fig. 26.) A simpler convection box may be made by cutting a hole near one end of the cover of a long pasteboard box, and another in one end of the box. Stand the box on end and stand the candle end inside. Place the cover on, with the hole near the candle. (See Fig. 27.) Touch paper, enough to last indefinitely, can be bought from the apparatus companies for about five cents. A strip $\frac{1}{2}$ in. wide and 3 in. long is more than enough for a demonstration; string

or filter paper soaked in saltpeter (KNO_3) solution and dried is touch paper.

Method. — Place the lighted candle end in the box just under the place where one of the holes in the lid will be when the cover is on; replace the cover and place one of the cylinders over each hole. Let different members of the class place their hands just above the two chimneys; they will note the warmth above the chimney over the flame. Then light the strip of touch paper and hold it in turn over each of the chimneys. It will be evident to the class that the smoke travels down the chimney under which there is no candle, and up the other. The students should be able to conclude for themselves that the heat travels in currents, and that, therefore, *convection in air* is the transference of heat from one place to another by means of currents. If the pasteboard box is used, light the candle inside, and hold the touch paper near the lower hole; the smoke will be forced into the box and up out of the top hole.

No. 32. CONVECTION IN LIQUIDS

Materials. — Burner; test tube; water; sawdust, or a few *small* crystals of potassium permanganate ($KMnO_4$).

Method. — Shake up in a test tube of water a little sawdust, some of which will sink to the bottom. Hold the test tube over the flame of the burner, and it will be evident that currents are formed, which travel upward through the water. This same principle of convection in liquids may be shown in a much more pleasing way by dropping into the test tube of water the $KMnO_4$ crystals. When the test tube is now held over the flame, beautiful lavender currents will be visible rising through the water. *Convection in liquids* is, therefore, the transference of heat from one place to another by means of currents.

No. 33. CONDUCTION OF HEAT BY METALS

Materials. — Conductometer; paraffin; burner; evaporating dish or tin plate. A conductometer provided with four wires, brass, copper (Cu), aluminum (Al), and iron (Fe), can be bought from the apparatus companies for a few cents.

Method. — Before class, heat the paraffin in the tin plate until it is fairly soft, and then dip the ends of the conductometer wires into it, until a small ball of paraffin has adhered to each wire. When the class is assembled, hold the junction of all the wires of the conductometer over the flame of the burner, and require the students to note the order in which the balls of paraffin fall off the metal wires. The class should be able to infer that the heat passes along the wires from molecule to molecule, that, therefore, *conduction of heat* is the passing of heat from molecule to molecule in a substance. The metals in order of their heat conductivities are Cu, Al, brass, Fe.

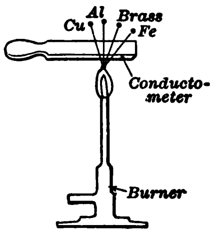

FIG. 28 (S).

No. 34. RELATIVE SPEED OF CONDUCTION AND CONVECTION IN WATER

Materials. — Burner; test tube of water.

Method. — Hold the test tube by the bottom with the flame playing near the top of the water in the tube. Do not let the flame touch the glass above the water, lest the heat break the glass. The water above the flame will soon boil. Allow different members of the class to feel the bottom of the tube to see that it remains cold. Make a holder for the test tube by folding a piece of paper into a narrow strip and placing it around the top of the tube with the ends in your hand. Now hold the bottom of the tube over the flame and the water will

soon be boiling. The class should be able to conclude that heat is transferred more readily in water by convection than by conduction.

Answers. — **1.** The air around the candle flame expanded because of the heat, and therefore became *less dense* (not lighter) and was then *pushed up* (it did not rise) by the colder, denser air, which was *forced in* (it did not rush in) by the greater pressure of the surrounding air.

2. See Answer 6, No. 50.

3. Heat is *conducted* through the iron into the water in the coils of pipe in the stove; the water becoming warmed, expands, becomes less dense, and is pushed up by the denser cold water into the top of the hot-water boiler. The principle of the gas heater is the same. In both cases the water in the tank is heated by *convection*.

4. The air coming in contact with the ice cools, contracts, becomes less dense, and is pulled down by gravity to the food below, the less dense warm air being *forced* to the top where it in turn is cooled by the ice.

5. The dust is carried up by the convection currents.

6. In an aluminum pan, because it is a better conductor of heat than iron.

7. Out of a porcelain cup, because porcelain is a poorer conductor of heat than aluminum, which conducts or conveys the heat so rapidly that it sometimes burns the mouth.

8. A metal.

9. The heat is conducted so slowly through the glass that the neck expands before the stopper does. The metal of a fruit jar cover expands likewise much more quickly than the glass neck of the jar.

10. If hot fruit is poured into cold jars, the inside of the jar becomes hot and begins to expand. But glass is so poor a conductor of heat that the outside of the jar does not become hot quickly enough to cause an equal expansion, and hence the unequal expansion of the glass causes the jar to break.

11. "The thermos bottle is designed to keep heat in or out, as desired. It consists of two bottles blown one inside the

other and sealed together at the neck. The outside of the inner bottle, and the inside of the outer bottle are silvered, then the air is pumped out of the space between the bottles, and this space is sealed air-tight. There are three ways in which heat moves from one place to another, namely, by conduction, by convection, and by radiation. Let us first consider that the bottle contains a cold substance and determine how heat is kept out of the bottle. Heat does not pass through the sides of the bottle by radiation because, when the heat waves reach the bottle, they are reflected by the bright silvered surfaces in the same way that light is reflected by the silvered surface of a mirror. A small amount of heat, however, can pass into the bottle by radiation down the neck. Heat does not enter the bottle by convection because there is no gas or liquid in the space between the bottles in which convection currents can form. It does not enter the neck of the bottle by convection because the substance is cold and the air in contact with it is colder and denser than the warmer outer air; therefore no convection currents can occur. Heat does not pass through the sides of the bottle by conduction, because there is a vacuum between the bottles, and a vacuum does not carry heat by conduction. Heat does, however, enter the bottle by conduction down the glass neck of the bottle. This is a slow process, because glass is a poor conductor of heat. The neck of the bottle is the door by which heat enters the bottle. It enters here slowly, partly by conduction and partly by radiation. It is probable also that a little heat is absorbed by the silver surface of the outer bottle and is conducted by the silver to the coating of the inner bottle and thence through the glass to the substance. If we consider the bottle to be filled with a hot substance, and think of the ways in which heat is retained, we find that it is retained in each of the ways that it is kept out when the substance is cold."[1]

12. "Heat escapes, however, in one more way than it enters the bottle. It escapes by convection in the air in the neck of the bottle."[1]

[1] Lynde, *Physics of the Household.*

13. "The fireless cooker is a box in which one or more pails are surrounded by a thick layer of non-conducting material. The substance to be cooked is placed in a pail and heated thoroughly. The pail is then placed in the box, and the heat contained in the substance slowly completes the operation of cooking. The non-conducting material may be felt, feathers, mineral wool, cotton, straw, shavings, etc. The non-conducting property of these substances is due largely to the air they contain."[1]

No. 35.

RELATIVE HEAT CONTENT (SPECIFIC HEAT)

This experiment upon "specific heat" is merely a qualitative one and is intended only to show that heat and temperature are *different* things, and that different substances have *different* heat capacities, but no attempt is made to show numerically the specific heats of the various substances used. The term "specific heat" is not used in the student part of this experiment, as it would require explanation sure to be difficult and confusing.

Materials. — Balances; 50 g. each of water (consider 1 c. c. of water to weigh 1 g.), tacks, shot, and (if you have access to a chemistry laboratory, and wish to use more substances) pellets of aluminum, and copper turnings; tumblers or beakers, each containing the same amount of water, one for each substance to be used; a large vessel, such as a pail, of water; stand and burner; thermometer; thin glass tumbler or beaker.

Method. — Before class, weigh out the equal weights of the different samples you are going to use. Place in the pail the thin glass tumbler, or beaker, containing one of the samples. Pour water into the pail nearly to the top of the tumbler and bring the water to a boil. Allow the water to stand in the other tumblers long enough to insure that all will be of the same temperature as the room. When the class assembles,

[1] Lynde, *Physics of the Household*

explain that the samples are all of the *same weight*, and that you are going to bring them all to the *same temperature* by putting them into the tumbler inside the boiling water. Explain that you are then going to drop them into *equal amounts* of water all at the *same temperature*, to see whether *equal* weights of all the *different* substances at the *same* temperature will produce the *same*, or *different*, temperature changes in equal amounts of water at the same temperature.

Stir the samples with the thermometer as they heat, in order to be sure that they become equally and thoroughly heated. When they have reached the temperature of boiling water, drop them one at a time into the tumblers of water, and stir the water with the thermometer, noting the approximate temperature when it ceases to rise any farther. It will be obvious to the class that the hot water raises the temperature of the water in the tumbler most, aluminum next, then, in order, iron, copper, and lead.

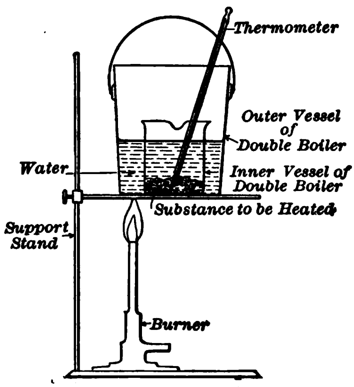

FIG. 29 (S).

As this experiment takes some time to demonstrate, it may be well to allow the students first to draw the figure, then to write up the method, while you are heating all the samples except the first. You can stop them long enough to allow them to see the readings of the different tumblers taken when subsequent samples have been heated to the proper temperature.

Answers. — **1.** Hot water, because it would contain a greater quantity of heat.

2. The metal balls would not melt the same quantity of paraffin, because no two would have equal heat capacities.

3. It takes the water longer to heat during the hot season, or during the day, and longer to cool during the winter, or at night.

4. The iron. Because of its smaller heat capacity, the same amount of heating will raise it to a higher temperature than it would an equal amount of water. Similarly, conditions being the same for each, the iron will cool proportionally faster than the same weight of water. This is analogous to filling a large and a small vessel. A little liquid will reach a higher level in the smaller vessel.

5. The contents of the inner boiler cannot become warmer than the temperature of the water in which it is placed, hence the food in the inner vessel remains at the boiling temperature, and can get no hotter, no matter how hot the fire underneath.

No. 36. CAPILLARITY

Materials. — Cube of sugar; powdered sugar (or flour); plate or watch glass; ink (red preferably, as it shows up better); medicine dropper or fountain-pen filler.

Method. — Cover the top of the cube of sugar with powdered sugar or flour, as deep as it can be piled upon the cube. Place the cube in a small pool of ink upon the plate. The rise of liquid through the pores of the loaf, and the failure of the liquid to continue through the non-porous powdered sugar will be apparent to the class. Of course the powdered sugar will dissolve, but very slowly.

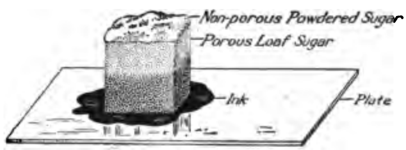

FIG. 30 (S).

This experiment can be, perhaps, more conveniently performed as follows: Place the covered cube upon a dry plate, and with the medicine dropper add on the lower edge of the cube as much ink as the cube will absorb.

Answers. — 1. Liquids will rise through tubes when they can wet the sides of the tube. There were no tubes in the

powdered sugar. Liquids are depressed in tubes they cannot wet (mercury in glass tubes, for instance). The elevation in the first case and the depression in the second are proportionally greater, the smaller the tubes.

2. Sandy soil is more porous than clay.

3. Water rises to the surface by capillarity or capillary attraction, and is there evaporated by the heat of the sun.

4. See Answer 4, No. 93.

5. See Answer 5, No. 93.

6. Capillarity.

7. Through ducts distributed throughout the stem (monocotyledonous plants); in the sap-wood near the bark (dicotyledonous plants).

8. Capillarity and osmosis. (See No. 114.)

9. Cloth is porous, while the pores of newspapers are closed to prevent the spread of ink.

10. Oil rises through the wick by capillarity.

No. 37.

DIFFUSION OF LIQUIDS AND SOLUTIONS

Materials. — Two small test tubes; alcohol; water; a crystal of potassium permanganate ($KMnO_4$), the size of the head of a pin, or a crystal of blue vitriol ($CuSO_4$) or a crystal of copper nitrate ($Cu(NO_3)_2$), the size of a pea, or a crystal of potassium dichromate ($K_2Cr_2O_7$).

Methods. — I. About a week or more before you want the class to write up the experiment, in the presence of the class, fill one of the test tubes three fourths full of water, and tilting it slightly, *very carefully* pour alcohol down the side of the tube to a depth of an inch or so above the water surface. A very obvious ring will be visible where the alcohol comes in contact with the water, but you may have to make several trials before you succeed in getting this ring.

II. Fill the other test tube with water and drop in the crystal ($KMnO_4$ gives the most satisfactory results). Call at-

tention to the ring in the first test tube and to the lack of color at the top of the water in the second, and tell the class that you are going to put the two tubes away where nothing can shake or stir their contents. In about a week the alcohol and water will have diffused so that the ring will have entirely disappeared, and also the milky color which is visible for the first two or three days, where the alcohol and water are diffusing. (See Fig. 31.) The tube of $KMnO_4$ will be almost a uniform pink color; if either $CuSO_4$ or $Cu(NO_3)_2$ is used, it will be a pale blue-green; and the $K_2Cr_2O_7$ produces a yellow solution. (See Fig. 32.) The class will be able to deduce that the results are due to the fact that the molecules in their rapid motion have become all intermingled, and that the intermixing accounts for the uniformity of color (the solid first having dissolved in the liquid).

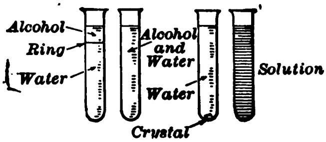

FIG. 31 (S). FIG. 32 (S).

No. 38.

DIFFUSION OF GASES WITH EACH OTHER

Materials. — Bell jar or fruit jar; pneumatic trough or dishpan; piece of rubber tubing; tumbler; support stand; diffusion cup of unglazed porcelain, with the end sealed with sealing wax and fitted with a brass tube. This piece of apparatus may be obtained from the laboratory supply houses complete at small cost, or may be improvised from a porous cup such as is used to make a two fluid (Daniel) cell for laboratory use, sealing wax, and a piece of glass tubing a foot long. (See Fig. 33.)

Method. — Fill the tumbler with water and arrange the diffusion cup above it on the stand so that the tube from the cup extends below the surface of the water in the tumbler. (See Fig. 33.) Fill the jar with hydrogen generated and collected as in No. 69 (or illuminating gas will serve very

well). Merely attach the rubber hose to the gas jet and collect the jarful of gas by the water displacement method as employed in Nos. 67 and 69. When the jar is full of gas, keeping the mouth of the jar down, place the jar of gas quickly over the porous cup, directing the attention of the class to the end of the tube in the tumbler. Bubbles will issue from the end of the tube. Explain that the student is to supply the word *gas* or *hydrogen* wherever there is a blank in his outline.

Conclusions. — 1. Greater.

2. This greater pressure in the cup forced bubbles out until the pressure inside the cup and that upon the surface of the water in the tumbler became equal.

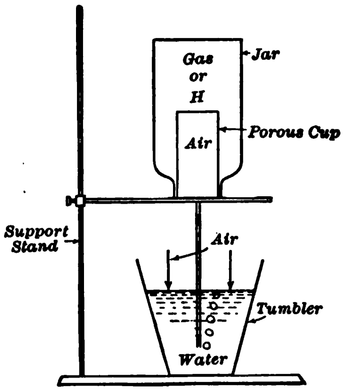

FIG. 33 (S).

Answers. — 1. Diffusion. The molecules of ammonia travel by means of their own motion and the air currents into all parts of the room.

2. Water, because in No. 37, I, the alcohol remained above the water in the test tube.

3. Air molecules did of course travel out through the porous cup into the jar, but they traveled so much more slowly than the gas molecules came in, that their departure was not sufficient to offset the arrival of gas molecules, hence the increase of pressure in the cup.

4. Less. A partial vacuum or reduced pressure would then have been produced in the cup, owing to the departure of the gas molecules faster than air molecules could diffuse in through the cup to take their places. As a result, water would probably have been forced up the tube into the cup by the greater air pressure upon the surface of the water in the tumbler.

No. 39. WEIGHT OF AIR

Materials. — Burned-out electric globe (as large a one as possible); something with which to remove the tip (pliers are perhaps as good as anything else); paper bag; balances and weights.

Method. — Place the burned-out electric globe in the paper bag and weigh it carefully to the nearest tenth gram. Then by means of the pliers, and still keeping the globe inside the bag in order to catch all the pieces of glass, break off the tip of the globe. The class will probably be able to hear the whistling of the air as it is forced into the globe. Reweigh the globe in the bag to the nearest tenth gram. There will probably be at least two-tenths gram difference in the two weighings, depending upon the size of globe used. It is useless and undesirable to attempt to do more than merely indicate that the globe filled with air weighs more than one unfilled, as the students are too immature, and the apparatus too roughly accurate, to give success to a careful quantitative experiment. The class should, however, be able to determine for themselves that air has weight. The Method write-up should contain a statement of the weight of the globe before and after removing the tip, and the difference in the weights.

No. 40. PRESSURE OF AIR

Materials. — Burned-out electric globe; something with which to break off the tip (pliers are as good as anything else, perhaps); battery jar, bucket or pan of water, large enough to accommodate your hands and the globe at the same time.

Method. — Call attention to the emptiness of the globe, and then place the globe under water, metal end down, with the globe tip an inch or two under the surface. With the pliers break off the tip of the globe, calling attention meanwhile to the rapidity with which the water fills the globe. Show the class that the globe is now full of water. It should be obvious to the class that air exerts pressure.

No. 40. PRESSURE OF AIR (Alternative)

You may prefer this experiment to the previous one, as it is more spectacular, though less easy.

Materials. — Perfectly tight can with cork or rubber stopper to fit it tightly; burner; water; support stand.

Method. — Pour water into the can to the depth of ½ in. and, placing the can on the support stand, apply the heat of the flame until the water is boiling vigorously. Then quickly remove the flame, and as quickly as possible force in the cork or stopper *tightly*, so that the can is air-tight. If the cork is not *perfectly* tight, the experiment will be a failure. Remove the can and pour cold water over it. The sound of the water's continued boiling in the can will probably be plainly audible. Soon the can will be dented by the force of air pressure, and shortly it will be crushed in. (See Fig. 34.)

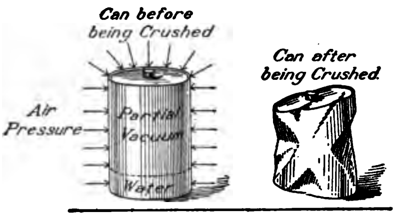

FIG. 34 (S).

Answers. — **1.** A partial vacuum. This will be *almost* a perfect vacuum, — a perfect vacuum cannot be produced artificially.

2. The readings were taken hastily, and neither the balances nor the weights are likely to be very accurate.

3. (Globe.) When the tip was removed, since there was a partial vacuum in the globe, the pressure existing inside the globe was so much less than that of the air upon the surface of the water, that the water was immediately *forced* into the globe. (Can.) As the cold water cooled the can, the steam inside was condensed, resulting in a partial vacuum or reduced pressure within the can. The greater pressure of the air outside, therefore, *forced* in or crushed in the can.

4. To the weight of the air or the water column existing above the *unit of surface* (sq. cm. or sq. ft.) upon which

the pressure is exerted. The height of this column of air or water is always measured *vertically* from the upper limits of the air, or from the water surface, to the point where the pressure is exerted, no matter what the shape of the containing vessel. The total pressure exerted upon a unit of surface under water is of course the weight of the water column plus the weight of the air column above this unit of surface. Thus at a depth of 34 ft., in fresh water, the actual pressure is two atmospheres. (See Answer 2, No. 42.) Gravity causes the air and water to have weight.

5. The final weight would have been the same, whether the globe was smashed and the pieces saved, or whether it was merely punctured, because, in either case, there would have been added to the air column above the pan of the balance, a volume of air equal to the volume of the globe (formerly almost a vacuum). Hence the same increase in the weight of the globe would be registered, whether it were shattered or punctured. Think of a vacuum as being merely a bubble in the air.

6. The function of the cold water was to condense the steam inside the can, thus diminishing the pressure inside the can. As the pressure was diminished, the boiling point was lowered; *i.e.* as the pressure inside the can became less, the water was able to boil at a much lower temperature.

7. The boiling point becomes lower as the pressure is decreased. For example, water boils at 0° C. when the pressure is reduced to .46 cm. See preceding answer.

No. 41. THE SIMPLE BAROMETER

Materials. — A 36-inch glass tube closed at one end (see Introduction); small-lipped beaker or tumbler; larger beaker or tumbler; clean mercury (Hg); meter-stick.

Method. — In the presence of the class fill the tube with Hg. This can be done without spilling any of the Hg, by grasping the tube so that part of the hand projects above to

act as a crude funnel for the Hg, or by pouring the Hg from a tumbler through a small funnel of paper, or by pouring the Hg directly from the small-lipped beaker. Holding a finger tightly over the end of the tube, invert it into the larger beaker of Hg, being careful not to allow the finger to slip off until the end of the tube is well below the surface of Hg in the beaker. Before you remove your finger, call attention to the Hg in the top of the tube, which will subside some distance when the finger is removed. Also call attention to the fact that the end of the tube has been below the Hg surface meanwhile, so that *no air could enter the tube.* The height of the Hg column measured from the Hg surface in the beaker can be taken in inches and centimeters, by means of the meter-stick. The class will be able to conclude unassisted that a vacuum was in the tube above the Hg, and that the column was supported by the pressure of the air upon the Hg in the *beaker.*

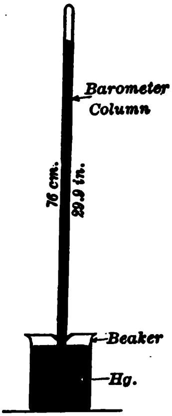

FIG. 35 (S).

Answers. — **1.** The weight of one column exactly balances and equals the weight of the other. (See Answer 5, No. 48.)

2. The Hg in the barometer tube would immediately have descended to the level of Hg in the beaker because there would then have been equal pressure upon the Hg inside the tube and upon that in the beaker.

3. There would have been no Hg column in the tube, because there would have been no air pressure upon the Hg in the beaker to support the column in the tube.

4. Less high on the mountain because of the decreased density, and hence the decreased pressure of the air, and higher in a mine because of the increased density, and hence the greater pressure of the air.

5. A crude, simple barometer could be made of many liquids other than Hg, but for water such a tube would have to be more than 34 ft. high, and for gasoline still higher, be-

cause of the smaller density of these liquids as compared with Hg.

6. The cheeks, lower jaw, and tongue lift part of the pressure off the front part of the mouth cavity, or reduce the pressure existing there. Then the air pressure upon the surface of the lemonade in the glass *pushes* the liquid into the mouth.

No. 42. THE SIPHON

Materials. — Two tumblers or beakers; piece of rubber tubing, or glass tubing which has been bent (the rubber tubing is better); water. See Introduction, for method of bending glass tubing.

Method. — Partly fill the two tumblers with water, then fill the tubing by first inverting it and pouring water into one end while holding both ends at the same level. Pinch both ends of the tube together and place one end in each tumbler. Place one tumbler upon books or in some other way raise it to a level higher than the other. Call attention to the flow of water through the siphon, as evidenced by the change of water levels in the two tumblers. Slowly raise the lower tumbler until its water level is above that of the other tumbler. Lower and raise this tumbler several times until the class has been able to note unassisted that the water flows from the vessel having the *highest water level.* At some time during this demonstration, allow the upper vessel to have much the smaller quantity of water in it, so that no student will infer that the water flows from the vessel containing the greater quantity of water to that containing the lesser quantity.

Refill the upper tumbler and raise it upon books until the lower end of the tube is over, but not in, the second tumbler. Then, as the water flows, slowly raise and lower the lower end of the tube until the class has been able to conclude unassisted that the greater the difference between levels, the faster the water flows. You will probably need to explain that when the

water flows directly from the tube and not into another vessel, the lower end of the tube corresponds to the water level in the lower vessel. (See Fig. 37, and explanation.)

Answers. — **1.** In a vacuum, water could not be siphoned from one vessel to another; because there would be no air pressure to force the liquid over the bend in the tube.

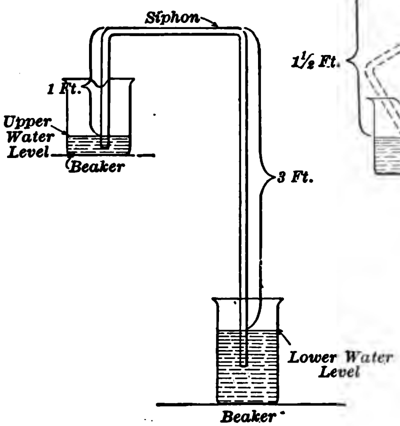

FIG. 36 (S).

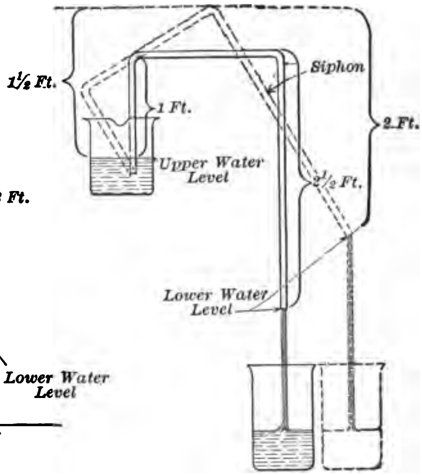

FIG. 37 (T).

The dotted line represents the siphon tilted so as to raise the lower end. Before the lower end was raised, the difference between the upper and lower levels was $2\frac{1}{2}-1=1\frac{1}{2}$.

But since raising the lower end also raises the bend, the difference in levels after the lower end was raised was $2-1\frac{1}{2}=\frac{1}{2}$ ft.

2. Atmospheric pressure is insufficient to lift a column of water higher than 34 ft. (actually only about 26 or 27 ft. because of friction and vapor pressure); but alcohol, the density of which is about .81 g. per cubic centimeter, as compared with water, the density of which is 1.00 g. per cubic centimeter, could be lifted nearly 42 ft. This means that a column of water 34 ft. high, or one of alcohol 42 ft. high, weighs as much as an air column having the same diameter as the water column or alcohol column, and extending to the top of the atmosphere.

3. Only about 76 cm., or 29.9 in.; a column of mercury 29.9 in. high weighs as much as one of water 34 ft. high, because of the difference in the densities of the two liquids.

4. It is not the length of the siphon tube which matters greatly, but it is the *vertical height* of the liquid column.

5. Because the air pressure is exerted where the water issues from the tube.

6. The atmosphere is able to support a column of water 34 ft. high; it *is* supporting a column of water in each arm of the tube *less* than 34 ft. high, and hence the remaining *effective pressure* of the air upon each side is that due to a column of water 34 ft. in height, minus the vertical height of the tube arm, measured from the water level to the bend. (See Fig. 36.) Since the remaining *effective pressure* upon the *upper* water level is therefore greater than the remaining *effective pressure* upon the lower level, water is *forced* from the *upper* vessel into the lower. The effective pressure upon the upper level is 34 ft. minus 1 ft. (see Fig. 36) or 33 ft., while that upon the lower level is 34 ft. minus 3 ft. or 31 ft.

7. No water would flow because the remaining effective air pressure would be equal in both arms.

8. In a siphon the bend of which is more than 34 ft. above the upper liquid level, water will part at the top and fall until the water column in each arm is 34 ft. high; but in a siphon less than 34 ft. high, there remains some effective pressure which tends to raise the water still higher, thus preventing the water from parting at the bend.

9. Fill the hose with water, close both ends, place one end in the water in the boiler and the other in the sink, or drain, or any vessel of which the level is below that in the boiler. The water will then be siphoned out.

No. 43. AIR PRESSURE AND THE LIFT PUMP

This has proved a very successful experiment, and is valuable in developing and fixing ideas regarding air pressure and how it may be utilized.

Materials. — Glass lift pump model; tumbler or beaker of water. A glass lift pump model can be obtained from the apparatus companies for about $1.50, but it may be well to have an extra one in reserve, as they are easily broken if the piston is not raised and lowered *exactly perpendicularly.*

Method. — Work the lift pump piston up and down until the students have noted for themselves that the valve (*a*) opens when the piston is descending and the valve (*b*) opens when the piston is ascending. It is easier to show this if the piston is raised and lowered by jerks.

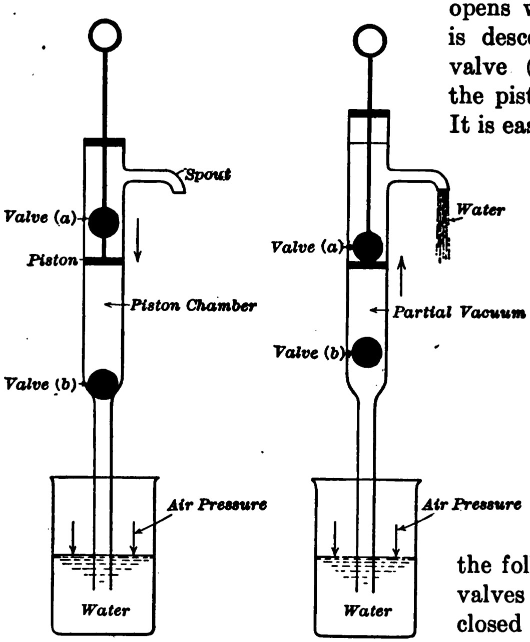

FIG. 38 (S).

The class should be able to make correct deductions with little assistance, and their answers should contain some such statements as the following: 1. The valves opened and closed alternately. 2. When the piston is pulled up, a partial vacuum or reduced pressure is formed in the piston chamber between the piston and valve (*b*). (A partial vacuum of *appreciable* size, however, is formed only when the piston is jerked upward very quickly.) The greater air pressure acting upon the water in the tumbler then *forces* the water *up* the tube, *pushing up* valve (*b*). On the downstroke of the piston, valve (*b*) is held down by gravity

and the pressure of the water above it, while (*a*) is ***pushed up*** by the water in the piston chamber. (It may be inadvisable to emphasize the fact that inertia tends to keep valve (*a*) open during the beginning of the downstroke, unless the students think of it for themselves. Such discussions belong in a more advanced course in physics.) 3. The water flows out of the spout during the upstroke.

Answers. — 1. Water could not be raised by a lift pump in a vacuum, because there would be no air pressure upon the water in the well or cistern, to force it up into the pump.

2. Wetting the leather causes it to expand and fit the piston chamber tightly, permitting a partial vacuum to be formed below the piston. If the packing around the valve were not tight, air would be forced in from above, and no partial vacuum would then be possible, and hence no water could be lifted by the pump.

3. See Answer 2, No. 42.

4. In the vacuum cleaner, a partial vacuum is created into which the greater air pressure outside, pushing through the carpet, forces the dirt into a bag or other receptacle on the cleaner.

No. 44. DEW POINT

Materials. — Set 1. Thermometer (Centigrade preferably); bright tin cup or can; finely chopped ice; water. Set 2. Centigrade thermometer; dew-point apparatus according to Professor Millikan, which consists of a metal (brass) vessel fitted with a three-hole stopper, a pipette, and tube with aspirator bulb; ether. The dew-point apparatus may be bought complete without thermometer for about seventy cents, from the apparatus companies.

Method. — (Using Set 1.) First take the room temperature. Then fill the can half full of cold water and add a handful of chopped ice. Stir with the thermometer, instructing the class to note the instant moisture begins to collect upon the surface of the can, that is, when first the surface becomes

clouded. As soon as this happens, again take the temperature of the ice and water. Explain that this temperature is the dew point. (See Fig. 39.)

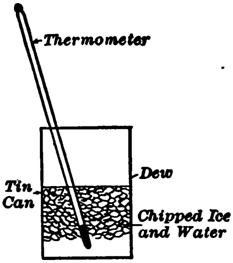

FIG. 39 (S).

(Using SET 2.) First take the room temperature. Then fill the metal vessel half or two thirds full of ether, insert the cork, through which the pipette, aspirator tube, and thermometer project, the latter two projecting into the ether. (See Fig. 40.) Gently force air through the ether by means of the aspirator bulb. As the ether evaporates, the temperature of the vessel will fall rapidly, since the effect of pumping air through the ether is to increase the evaporating surface of the ether, and hence to increase the rapidity with which the temperature falls. As soon as moisture begins to cloud the surface of the metal vessel, take the temperature, informing the class that this is the dew point. In both methods the student will be able to infer that the room would have to be cooled to the dew point before the moisture in the air would begin to precipitate. In neither case will this experiment be very accurate, as it is impossible in this way, especially with only one trial, to determine the dew point exactly, but extreme accuracy is unnecessary in this course, since the *principle* is the important thing. Be sure that nobody breathes upon the can or vessel while it is being cooled, as the breath moisture will immediately cloud the vessel surface, producing a false dew point.

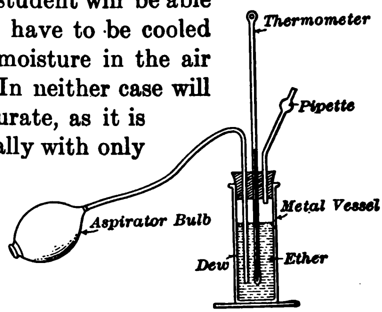

FIG. 40 (S).

No. 45. FROST POINT

Materials. — Centigrade or Fahrenheit thermometer, preferably the former; bright can or tin cup; chopped ice; salt; cold water. If desired, the dewpoint apparatus, described in No. 44, may be used.

Method. — Fill the can half full of water and add a small handful of chopped ice and about the same quantity of salt. Stir the contents with the thermometer. Dew will form when the dewpoint is reached; but if the stirring is continued, when the can reaches the freezing point of water, the moisture on the outside of the can will freeze. Explain that this is not frost, but merely the dew which has frozen, and call attention to the moisture which collects upon the can from this point on. This will be *frost,* for the moisture freezes as it deposits. This frost will be different in appearance from the frozen dew, being less compact. The *frost point* in this case, therefore, will be the freezing temperature of water; but if the experiment can be performed during a cold spell in winter, when the saturation temperature of the air is *below* the freezing point of water, no dew will form first. The first moisture visible upon the surface of the can, therefore, will be frost, and the frost point will be below the freezing point of water. If the dewpoint apparatus is used, the same method as explained in No. 44 may be employed,.the process being continued until frost forms; dew will, of course, form first, as explained above.

The diagrams for this experiment are the same as Figs. 39, 40, except that the word "frost" is written in place of "dew," and "chipped ice, salt and water," instead of "chipped ice and water."

No. 46. RELATIVE HUMIDITY

It has been found more satisfactory with this experiment to give the class a full explanation to assist them in determining the relative humidity than to attempt to teach them by ordinary demonstration or oral explanation. Students should find this

assistance adequate, but many of them will need additional help. As little aid as possible should be given, however.

Materials. — Temperature of the room and the dewpoint, both found in working out No. 44; table of vapor pressures and temperatures on page 35 of the PUPIL'S MANUAL.

Method. — In column (T) find the room temperature, and take from column (P) the corresponding vapor pressure. Similarly, take the vapor pressure corresponding to the dewpoint. Divide the vapor pressure at dewpoint by the vapor pressure at the room temperature, and multiply by 100, for the per cent of saturation, or relative humidity. If you use a Fahrenheit thermometer, reduce the readings to Centigrade, so as to fit the table, by using the following formula: $C.^\circ = \frac{5}{9}(F.^\circ - 32^\circ)$. Thus, to reduce 68° F. to C.°:

$$C.^\circ = \tfrac{5}{9}(68\text{–}32) = \tfrac{5}{9}(36) = \tfrac{180}{9} = 20^\circ \text{ C.} \quad \textit{Ans.}$$

Answers. — **1.** Absolute humidity is the actual amount of water vapor present in the air, and is usually measured in the number of grains of water actually present in a cubic foot or grams in a cubic meter. Saturated atmosphere is atmosphere which holds all the moisture it can without raising the temperature. Dewpoint is the *temperature* at which the actual amount of vapor in a space is sufficient to saturate it, or it is the *temperature* at which dew begins to deposit.

2. From the air around the vessel. Had there been no air in the room, and only water vapor, the moisture would have been deposited just the same. The air around the vessel was cooled to the temperature at which it became saturated, and below which the air could no longer hold as vapor all the moisture in it. The moisture in the space around the vessel was not all precipitated; the air immediately around the vessel continued to be saturated as long as any dew was depositing from it.

3. 100%.

4. Raising the temperature *decreases* the relative humidity, because while the absolute humidity, or *amount* of vapor in the space, is not changed, the warmer air is able to hold as vapor a greater quantity of water than it could before the temperature

was raised. Therefore, since relative humidity is the absolute humidity divided by the amount of moisture the space *could* hold if saturated, raising the temperature decreases the relative humidity, by increasing the denominator of the relative humidity fraction without correspondingly increasing the numerator (absolute humidity). Similarly, lowering the temperature *increases* the relative humidity by decreasing the amount of vapor the space could hold (denominator) without changing the absolute humidity (numerator).

5. Frost is not frozen dew, nor is snow frozen rain. Frost and snow are formed when the precipitation of vapor takes place below the freezing point of water, and therefore the *vapor freezes as it deposits*, *i.e.* it passes from the gaseous to the solid state without passing through the liquid state. Vapor is essentially gas, and since all known gases are unquestionably capable of liquefaction, no physical difference can be said really to exist between an ordinary gas (such as oxygen) and a vapor (such as steam). "It would be an error to confound clouds or fog or any visible mist with the *vapor* of water. . . ."[1]

6. " . . . rain on its way down may freeze in passing through a cold layer of air, forming sleet. Some sleet is snow that has partly melted, and then frozen before reaching the ground. . . . Hail is formed in violent storms, such as tornadoes and thunderstorms, where there are strong, whirling currents of air. Hailstones are balls of ice, built up by condensing vapor as they are whirled up and down in the violent currents, freezing, melting, and freezing again as they pass from warm to cold currents. For this reason they are often made of several layers, or shells, of ice."[2]

7. Conditions being the same, dew may be *precipitated* as readily upon the under surface of any suspended cold body as upon the upper surface.

8. Moisture-laden winds (prevailing westerlies) from the Pacific are cooled when they reach the western slopes of the Cascade Range; their relative humidity is increased, and most of the moisture is precipitated as rain. When the winds cross

[1] Tyndall, *Radiation*
[2] Tarr, *New Physical Geography*

the mountains, therefore, and descend into the warmer plains, they become dryer; *i.e.* the relative humidity becomes less.

9. 50% to 70%.

10. The cold outdoors may have a fairly high relative humidity at its temperature, but when this same air is brought into the house and warmed, the relative humidity becomes very much less. (See Answer 4, page 60.)

11. The evil effects come from "the *change* we necessarily encounter when we are obliged to step from an indoor atmosphere heated to 70° with a humidity of 20%, into an outdoor atmosphere at 20° with a humidity of 80%."[1]

12. ". . . the human body is constantly moist; more or less evaporation is constantly taking place from the skin. While the clothing, by inclosing an envelope of air about the body, checks this evaporation somewhat, still, if the air in the room is in as rapid motion as it should be, we feel decidedly the chilling effect of evaporation. One is more comfortable in a room heated to 65° with the humidity 50%, than in a room heated to 70° with the humidity 20%."[1]

13. "The body is constantly giving off heat, and if the air is quiet, the portion close around the body will soon get much warmer than the rest, as if the body were surrounded by a kind of blanket of hot moist air. A wind breaks up this layer and brings fresh cool air to the body all the time; this is why it is so much more comfortable outdoors, or with an electric fan running, than in a closed room with still warm air."[2]

14. ". . . the mucous membranes of the nose are constantly congested (filled with blood and lymph), as the blood vessels dilate to keep the body at the proper temperature. As a consequence, these membranes — instead of shrinking and drying promptly, as they should, when they come in contact with cold outer air — lose their quickness of response and stay moist and swollen after the blood vessels themselves have contracted; this makes them an excellent breeding place for bacteria."[2]

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[1] Barber, *First Course in General Science*
[2] Winslow, *Healthy Living*

No. 47. FOG

Materials. — Large bottle into which is fitted a single-hole rubber stopper; short piece of bent glass tubing; rubber tubing; compression pump (a cheap bicycle pump serves admirably); water; match.

Method. — Connect one end of the rubber tubing to the outlet from the pump, and fit the other end tightly over the end of the glass tubing which has been tightly fitted through the hole in the rubber stopper. When the pump has thus been connected to the stopper, put about an inch of water into the bottle, and fit the stopper in tightly. Let a student hold the stopper firmly in the bottle, to prevent breakage of the glass tube because of sudden strain. I. Pump several strokes, then remove the stopper. There will be no visible result. II. Light the match and when it is burning well, drop it into the bottle, and again stopper the bottle tightly. Again pump several strokes. Remove the stopper. Immediately a dense fog cloud will form in the bottle. This fog cloud can be dispelled by again inserting the stopper and forcing more air into the bottle, but the fog will reappear when the stopper is again removed.

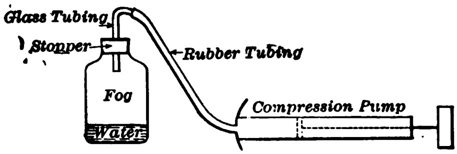


FIG. 41 (S).

It may be well to explain to the class as you go along. When air is compressed, it becomes warmer and therefore can evaporate more water. When the stopper is removed, the compressed air immediately expands, and is therefore rapidly cooled. When air is cooled, its relative humidity becomes greater, because while the actual amount of vapor in it has not been changed, it is unable to hold so much when cooled and is hence more nearly saturated at a lower temperature than at a higher one. But in this case the air in the bottle becomes saturated, and the excess moisture is deposited on the smoke and dust par-

ticles in the bottle. The class will be able to infer that lowering the temperature of a layer of air causes moisture to precipitate upon dust particles. When the air is recompressed, the increase of temperature causes the fog which has previously precipitated to reëvaporate, only to be redeposited when the air is again allowed to expand and therefore cool.

Answers. — 1. See explanation above.

2. There was not enough dust in the air. The smoke from the burning match furnished solid particles upon which the fog collected.

No. 48. STUDY OF A DAILY WEATHER MAP

This and the following experiment may be demonstrated from the weather reports, but the method indicated has been found much more successful.

Materials. — Weather reports. The nearest Weather Bureau will send you free of charge any number of weather reports for the same day. Let each student study one of these and work out the answers unassisted, if possible. Having all the papers based upon the same map simplifies their correction.

Answers. — 1. Temperature, pressure, humidity (moisture content), cloudiness, precipitation (which includes rain, hail, sleet, and snow), velocity, and direction of the wind.

2. They connect all points having equal pressures and are called isobars.

3. Choose cities some distance apart, each of which is about halfway between two isobars. The pressure at these cities will be approximately the sum of the pressures indicated somewhere on the two nearest isobars, divided by two.

4. Greater. More violent.

5. The weight of a column of air of any diameter, and extending to the top of the atmosphere, is normally equal to that of a column of mercury of the same diameter and 29.9 in. high.

6. Equality of temperature for all points on the same dotted line. Isotherms.

7. This question refers to the half of the sheet below the map itself. The items to be found there will depend largely upon the section of the country from which the report is issued, and will be for the most part local, such as river readings, bar readings, etc., but all reports will probably contain a large table of comparative temperatures, pressures, wind velocities, etc., for stations scattered over the United States, and Canada.

8. Rainy areas are shaded.

9. Benefits to irrigation projects, farmers, gardening and fruit interests (frost warnings); to shippers, railroads (cold warnings); to shipping offices and ships (warnings of gales on lakes, gulf, and coasts, flood warnings, conditions of bars, etc.); to irrigation projects (information relative to available water supply).

Diagrams. — (The arrows fly *with* the wind.)

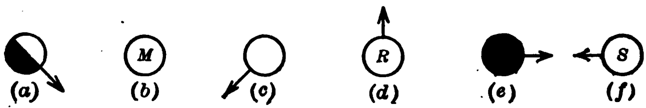


FIG. 42 (S).

No. 49. STUDY OF A WEEK'S WEATHER MAPS

Materials. — The nearest Weather Bureau will send you free of charge duplicate sets of weather reports for a whole week, six maps to a set. Cut off the bottom parts of the reports and paste just the maps in order, upon a large sheet of cardboard. One 25 by 24 in. is large enough, if you paste the maps in two vertical columns of three each. Write on the bottom of each map the day of the week it represents. Mark the highs and lows on the Monday map, *A*, *B*, *C*, etc., and mark the *same* highs and lows on the following maps with the same letters. This will be fairly easy to do, since the lows and highs usually move across the United States in a general direction from *west* to *east*. Keep in mind that highs and lows usually enter the United States from the Pacific, or through Montana or Dakota, though some develop in Texas and southwest-

ern New Mexico. Though sometimes they leave the United States in the southeast, usually they move east across the Great Lakes and out by way of the St. Lawrence River.

The experiment is most successful if not more than two students, or four at most, study each card. The class should be able for the most part to work out all the answers to the questions individually and unassisted.

Answers. — **1.** ——.

2. ——.

3. See explanation above.

4 and 5. Neither of these is ever a constant quantity, but will vary probably from a few hundred to more than a thousand miles.

6. These are also extremely variable quantities, ranging from about two hundred to sometimes over two thousand miles.

7. The terms *cyclone* and *low* are used interchangeably, though the latter is the more usual; similarly *high* is more commonly used than *anti-cyclone*. Because of the earth's rotation, both the highs and lows are rotating winds, the direction of the winds being from the highs to the lows because of pressure differences. The winds, therefore, move inward toward the center of a low and outward from a high center. There is a counter-clockwise rotation of air currents about a low in the northern hemisphere.

8. In a high, the currents settle and spread out in all directions, but again the earth's rotation causes a clockwise rotation about a high, in the northern hemisphere. In the southern hemisphere, the direction of rotation is exactly the opposite for highs and lows from what it is in the northern hemisphere, being clockwise for lows and counter-clockwise for highs.

9. This is always a widely variable quantity, but in winter it will be about eight hundred miles, and in summer, about five hundred.

It may be well to remind the pupils that the term *cyclone* as used frequently by newspapers to designate a small violently whirling storm is incorrect, the correct name for such a storm being *tornado*. A tornado is a small cyclonic wind, occurring

within the southeast quarter of a cyclone, traveling northeast. Its path varies usually only from about one hundred feet to fifteen hundred feet wide, and is usually but a few miles long.

No. 50. FERREL'S LAW

Materials. — Globe (the bigger the better, the blackboard globe used for the study of solid geometry being excellent for this purpose); tumbler containing a little water.

Method. — Holding the axis of the globe vertical, rotate the globe rapidly in a counter-clockwise direction as looked at from above, that is, from left to right as you face it. Let one of the students pour a little water upon the top of the rapidly rotating

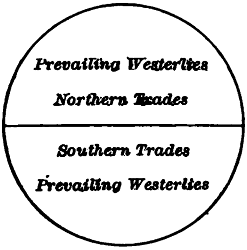


FIG. 43 (T).

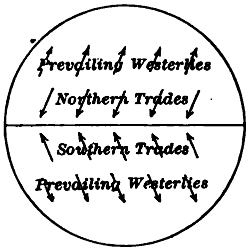


FIG. 44 (T).

globe, just enough so that a few slender trickles run down the globe. Call attention to the path of these water-trickles, which will be marked on the globe as in Fig. 46. Then draw on the blackboard a diagram corresponding to Fig. 43. Indicate on the floor a line to represent the equator of the earth, and calling attention to the paths of the water down the globe and to the figure you have just drawn on the board, tell the class that you represent the northern trades, and that as you move toward the equator, they are to determine whether you should turn slightly toward your right or your left. They will tell you, that you should turn toward your right.

Step across the line and facing it from the opposite direction announce that you represent the southern trades, and again

approach the line, requiring the class, as before, to determine whether you should turn towards your right or your left, to be in accordance with the water paths on the globe and the diagram on the blackboard. They will tell you to turn toward the left. Now move several feet away from the line, on the side from which you first approached it, to represent the prevailing westerlies in the northern hemisphere. Calling attention to the water paths on the globe at a point about halfway between the equator and the north pole, and to the diagram on the board, require the class to determine as before, whether you should turn slightly to your left or your right as you move away from the equator. They will tell you toward your right. Repeat, for a corresponding position and movement away from the equator on the other side of the line, (southern hemisphere). The class will tell you, that you should turn toward your left. The class will now be ready for the following statement of Ferrel's Law: Because of the rotation of the earth, all winds in the northern hemisphere are deflected a little to the right of a person moving with the wind, and in the southern hemisphere, a little to the left of a person moving with the wind.

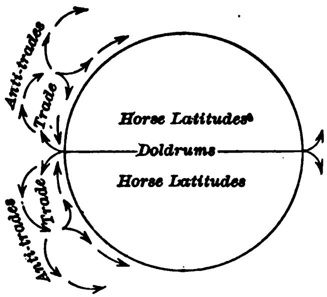


FIG. 45 (S).

The student will be able to infer the following conclusions to the experiment: (1) Northeast. (2) Southeast. (3) Southwest. (4) Northwest.

Answers. — **1.** (1) Terrestrial or planetary; (2) continental; (3) eddying or cyclonic. The planetary winds are the trade winds, antitrades, prevailing westerlies. The circumpolar whirls are not included, because recent polar exploration has proved that they do not exist. The continental winds include monsoons, which are seasonal over India, and, to a less degree the land and sea breezes. The cyclonic winds include cyclones, anticyclones, hurricanes, and tornadoes.

2. Equatorial Calms or Doldrums; Horse Latitudes or Calms of Cancer and Capricorn.

3. Air currents are rising in the Doldrums, and sinking in the Horse Latitudes, but since a rising or sinking current will not move a ship, these currents are not considered to be winds.

4. Stove: "(1) a movement toward the stove; (2) a rising above it; (3) an upper current away from it; and (4) a settling at a distance from it." Earth: "(1) a movement of air along the surface toward the equator; (2) a rising in the torrid zone; (3) an upward movement away from this zone; and (4) a settling north and south of it."[2]

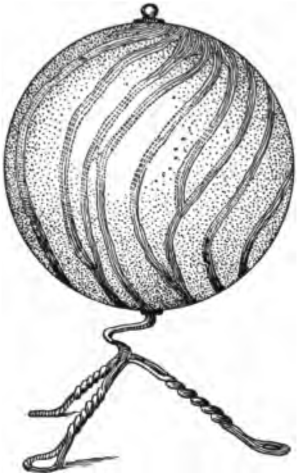


FIG. 46 (S)[1]

5. Wind is caused in every case by difference in atmospheric pressure at different points.

6. Because of the high specific heat of the ocean (it takes more heat to raise the temperature of water a degree than it does to raise the temperature of an equal weight of any other substance a degree), during the day the land heats more rapidly than the ocean. The air over the land, therefore, becomes warmer than that over the ocean, expands, becomes less dense, and is forced up by the greater pressure of the cooler air over the ocean. At night, because of the higher specific heat of the water, the land cools more rapidly than the ocean, and the warmer air is over the ocean. This air, therefore, expands, becomes less dense, and in turn is pushed up by the greater pressure of the cooler air over the land. In each case, the pull of gravity upon the columns of air over the water and the land causes the pressure which results in the

[1] Based on a figure in Caldwell and Eikenberry, *Elements of General Science*

[2] Tarr, *New Physical Geography*

motion of sea breeze during the day, and land breeze at night.

7. A cyclone is a low pressure area; from one to three of these low pressure areas pass across the United States every week, seldom causing any damage due to violent winds. For description of tornado, see the final paragraph of No. 49.

No. 51. REFRACTION OF LIGHT

Materials. — Coin; glass jar, tumbler or cup; water; pencil; piece of plate glass. A suitable Index of Refraction Plate can be bought from the apparatus houses for about twenty cents.

Method. — I. Place the coin in the bottom of the tumbler and tell the class to station themselves so that the coin is just invisible *above* the edge of the tumbler. Then cautioning them not to change position, but to watch just above the rim, pour water into the tumbler carefully so as not to move the coin. The coin will become visible above the tumbler rim. (See Fig. 47.) II. Draw a heavy black line upon a sheet of paper, place the plate glass over part of this line, and let the class look at the line *obliquely* through the glass. The line will appear bent where it enters and leaves the plate. III. Dip the pencil obliquely into the water. It will appear bent at a point where it leaves the water. The class will be able to infer that the objects merely appeared to change their positions; that therefore the light bent upon entering the air from the water and the glass; and that refraction of light is the bending of light as it enters a transparent substance of different density from that in which it has been traveling.

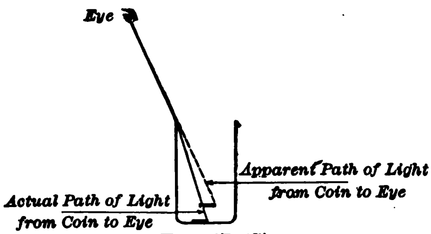


FIG. 47 (S).

Answers. — 1. Refraction at their irregular boundaries, as the light passes through layers of different density. There is a

rapid alternate increasing and diminishing of intensity of the beams.

2. Atmospheric refraction causes the light to reach us in a curving path which becomes slightly more nearly perpendicular the nearer it comes to the earth, because of the increasing density of the air. It must also be kept in mind that it takes about 8 minutes for light to travel from the sun to the earth.

3. The lower side appears higher with reference to the upper side than it really is, because the beams near the horizon are bent more than those farther away.

4. Refraction.

5. About a fourth nearer. (See Fig. 47.)

6. The surfaces of the glass are not plane to each other; hence refraction as the beams leave the glass produces the distortion.

No. 52. DISPERSION OF LIGHT

Materials. — Glass prism, such as can be obtained from the apparatus companies for about fifty cents; bright sunlight.

Method. — Hold the glass prism edgewise in the beam of sunlight, and, rotating the prism slightly, throw a colored spectrum upon the floor below the prism. Rotate the prism slightly so that the spectrum upon the floor is elongated, making it colored at the ends but white in the middle. The class will be able to infer that a prism separates white light into many colors of light, and that, therefore, dispersion of light is the separating of a beam of light into colored beams by means of a prism or by other means.

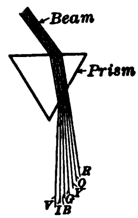


FIG. 48 (S).

Some assistance will doubtless need to be given the class in drawing the diagram, but the figure will serve to impress the facts of color dispersion upon the students' memories.

No. 53. ADDING COLORS TO MAKE OTHER COLORS

Materials. — A color top which, complete with colored disks, costs about eight cents from the apparatus companies.

Method. — It is perhaps well not to make more than two or three typical color additions or combinations, like those suggested below. It will not be possible with any combination on the top to produce anything nearer white than gray, because so few shades can be used on the top. One-third green and two-thirds violet give a good gray; two-thirds blue and one-third yellow give light blue-gray; one-half lilac and one-half yellow produce yellow-white. The following combination of *the three primary color sensations,* one-fourth *red,* one-half *green,* and one-fourth *violet,* produce light green. Explain to the class that the resulting color seen is due to the *addition* or *combination* of the different colors, and that this process is entirely different from that of mixing pigments or paints, which is a process of subtraction, the resulting pigment possessing the color which is not absorbed, or which is least absorbed or taken out, by the paints mixed.

Answers. — **1.** Refraction. Each color is bent at a different angle from all the others, because it has a different wave length. The violet, having the shortest wave length, is bent most, and red, having the longest wave length, is bent least. The unequal refraction of colored beams is due to the fact that the shorter the color wave, the greater is the retardation of its speed in passing through a refractive medium.

2. Gray is produced because the resulting color lacks brightness, and also because the few colors that we have at our disposal cannot produce white light, when the sunlight is composed of countless shades of color.

3. Dispersion of light through the raindrops, acting as lenses or prisms.

4. See explanation just preceding the Answers above.

5. The spectral colors are usually given as violet, indigo, blue, green, yellow, orange, and red. They are easily remembered by the word *vibgyor,* made up of the initial letters of the

seven colors. There is an overlapping of the colors in the middle of the spectrum thrown by the prism, with the result that where all the various colors overlap, white results. This also accounts for the fact that one end of the spectrum is violet while the other is red.

6. Two colors which, when added together, produce white light are said to be complementary colors.

No. 54. PRODUCTION AND TRANSMISSION OF SOUND

Materials. — Beaker or tumbler of water; tuning fork. An ordinary table fork will do for the second part of the experiment, but will not show the first part unless the class is small enough to allow all the students a close observation of the demonstration; and it will have to be repeated many times, and perhaps then will not be successful enough for the students to make correct deductions unassisted.

Method. — I. Strike the prongs of the tuning fork upon the table and immerse the prongs quickly in water, so that the prong ends are just beneath the surface. The *vibratory* motion will be very evident from the fact that the water will be thrown violently in both directions away from the sides of the prongs.

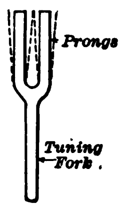


FIG. 49 (S).

II. Again strike the prongs of the fork against the table, and place the foot of the fork in turn upon several articles, such as, for instance, the table-top, a book, a loose wad of paper, the surface of the water. It will be evident that the more rigid the body, the better it will carry the sound.

Answers. — **1.** Sound travels only in matter, and hence will not travel through a vacuum.

2. The water is more dense than the air, the greater density here producing the same effect as greater rigidity in solids.

3. In a vacuum, longer than in air, and longer in air than in water, because there is less resistance to the vibration of the sounding body.

4. Ground (which is more rigid) carries sound more effectively than the air. It will probably be unnecessary to suggest to the class that this does not mean that solids are necessarily better transmitters of sound than air, but rather that the sound is more *intense* at the *source* when the medium carrying the sound is a solid.

STATIC ELECTRICITY

The four following experiments on static electricity will prove among the most difficult of the whole course, from the student's standpoint, but they have been found a very successful means of developing some of the more important facts of electrostatics. They will prove especially valuable in a school where the study of electrostatics is little emphasized in the physics course. The Discussion permits a fairly advanced presentation of electrostatics if desired.

To insure a thorough understanding of these experiments, they should be preceded, several days before, by careful demonstrations of the essential facts of static electricity such as are included in the experiments, particularly demonstration of the difference between charging by induction and by conduction.

By *conduction* is meant, bringing the body in *direct contact* with the charged body.

By *induction* is meant, charging an electroscope by merely bringing the charged body *near*, touching the electroscope knob or wire with a conductor, such as a finger, and *then* removing *first* the finger and *last* the charged rod. In demonstrating the different experiments on the days you want the class to make reports, it may prove best to do *nothing* outside of the *bare experiments*, themselves, to avoid confusing the class. Explain fully, as you go, what you are doing. It will save much time and effort, also, if you perform only a part of Nos. 57 and 58 at a time, allowing the students to write up each

part and receive correction on it before you demonstrate the next part.

All electrostatics experiments will be more successfully performed in cold weather when the relative humidity is low, as high relative humidity discharges a charged body rapidly. The sealing wax rod will probably take a minus charge stronger than the plus charge which the glass rod will take.

No. 55.
ELECTROSTATIC ATTRACTION AND REPULSION

Materials. — Ebonite rod or large stick of sealing wax; glass rod or tube; woolen cloth; silk cloth; induction cylinder. An induction cylinder may be made by clamping a metal rod at right angles to a stand, or perhaps an even better method for an elementary class is merely to take a wooden rod and secure it firmly. Make two small balls out of elder pith such as is used for making sections in the botanical laboratory, or the balls can be bought for a few cents a dozen from the apparatus companies. With a needle, string the balls on a silk thread, 8 or 10 in. long, and hang them over the end of the rod.

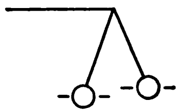


FIG. 50 (S). Induction cylinder charged minus.

Method. — Charge the sealing wax or ebonite rod by rubbing it upon a woolen cloth or upon your coat sleeve, and the glass rod by rubbing it *vigorously* upon the silk cloth. Bring the charged rods, one at a time, *near*, but not close enough to touch the pith balls, since then they would take the same kind of charge as that on the *rod*. Call attention to the behavior of the balls. They will be attracted by either the plus-charged or the minus-charged rods.

No. 56.

LAW OF ELECTROSTATIC ATTRACTION AND REPULSION

Materials. — Same as in No. 55.

Method. — Charge the neutral balls minus by contact with the minus-charged rod. This must be done carefully to insure both being charged from the rod by direct contact with *it*, and not with each other, during the charging. Bring the minus rod near them again after they are charged minus by contact with it, calling attention to the effect; they will both be repelled if the rod is not brought too close. Then bring the glass rod which has been rubbed with silk near the minus-charged balls and call attention to the effect; they will be attracted by the opposite sign. The student will be able unassisted to infer that like signs repel each other and unlike signs attract. If time permits, include as a part of the demonstration the same phenomena as illustrated above, but do the original charging of the balls with the plus rod, and the final testing with the minus rod.

No. 57.

BEHAVIOR OF A CHARGED ELECTROSCOPE WHEN APPROACHED BY THE SAME OR BY THE OPPOSITE SIGN

Materials. — Electroscope: sealing wax or ebonite rod; glass rod; woolen cloth; silk cloth. An electroscope may be made by running a heated copper wire through the middle of a short stick of sealing wax, which serves as an insulator. Cut a hole through a sheet of cardboard, and stick the sealing wax on the cardboard so that the wire projects down several inches through the hole. Attach a small strip of gold or aluminum leaf to the lower end of the wire (which has been previously bent), so that it hangs over in two leaves about an inch long. Place the cardboard over a battery jar or wide-mouthed glass vessel. Under ordinary conditions such an improvised electroscope will demonstrate all that is required for this experiment,

but a much more satisfactory electroscope insulated with amber may be obtained from the apparatus companies for about $1.25.

Method. — I. Charge the ebonite rod minus by rubbing it on your coat sleeve or upon a woolen cloth, and charge the electroscope minus by *conduction*, or *contact* with the rod. Then bring the minus rod near, but not any nearer than you have to in order to show that, when approached by the same sign, the leaves diverge farther. Call attention to this greater divergence of the leaves. II. Rub the glass rod *vigorously* on the silk and bring it *near*, but again no nearer than you need, to the minus-charged electroscope. Call attention to the effect; the leaves will converge. The students will be able to conclude that the leaves of a charged electroscope converge when approached by the opposite sign, and diverge farther when approached by the same sign.

No. 58.

CHARGING AN ELECTROSCOPE BY INDUCTION

Materials. — Same as in No. 57.

Method. — I. Divide the process of charging the electroscope by induction into *four* steps, number them one to four as you demonstrate them, and instruct the class to write up the experiment likewise in the four complete steps, stating in each step the behavior of the leaves:

1. Bring the minus-charged ebonite rod *near* the knob of the electroscope; the leaves diverge. (They would do this, of course, if the uncharged electroscope were approached by either sign.)
2. Place your finger upon the knob or end of the wire of the electroscope; the leaves converge.
3. Remove your finger; the leaves slightly diverge. Take care while you are removing your finger not to move the charged rod either nearer, or farther from, the leaves, else it will distract the attention of the class by causing the leaves to diverge or converge, respectively, as the rod is brought slightly farther from them or nearer to them.

4. Remove the rod; the leaves diverge farther.

II. Bring the minus-charged rod again near the electroscope charged by induction from the minus rod. Call attention to the behavior of the leaves; they will converge. Call attention to the conclusions of No. 57. The class with the above conclusions in mind should be able unassisted to infer that (1) the electroscope was charged plus by induction from the minus rod, since the leaves of the charged electroscope diverged less (converged), when approached by a minus sign, and (2) a body charged by induction has the opposite sign from that of the charging body.

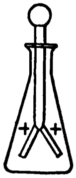


FIG. 51 (S).

Electroscope charged by induction from a minus rod.

Answers. — 1. Plus, since a body charged by *contact* or conduction takes the *same* sign that the charging body has.

2. A body attracted by a charged body is not necessarily charged, since a neutral body is attracted by either sign. (See No. 55 above.)

3. A body repelled by a charged body is proved to be charged, since only unlike signs repel each other.

4. (This may be easily shown by demonstration.) Being neutral, the balls will be attracted by the rod; but as soon as they touch it, they themselves become minus and are immediately repelled by the minus rod, and, at the same time, are attracted to the neutral finger (for a neutral body will attract a charged one as readily as a charged body will attract a neutral or uncharged one). The finger being a good conductor of electricity removes the minus charge from the balls, rendering them again neutral, whereupon they are again attracted by the minus rod, and so on, until the rod has lost all its charge to the balls and to the air, there being a constant "leakage" of charge into the air.

5. The minus charge necessary to neutralize the plus charge on the electroscope was prevented from returning along the finger by the minus charge on the rod, since unlike signs repel. If the rod had been removed before the finger, the electroscope

would have become neutralized at once. The plus was held on the electroscope because of the attraction of the minus charge on the wax.

6. Charge the electroscope *minus* by induction from a *plus* rod, and bring the unknown charge near the electroscope. If the leaves converge, the unknown charge is plus; if they diverge farther, it is minus.

MAGNETISM

While the two following experiments upon magnetism will prove among the most difficult in the course, they will serve efficiently to impress some of the basic facts regarding magnets. It may be well to demonstrate only a part of an experiment at a time, allowing the class to write it up before you demonstrate the next part. This arrangement will avoid much confusion, otherwise inevitable. It will also be found a saving of time and effort to allow the students to diagram the different parts of No. 60 as soon as you have demonstrated them, and before the class writes up the Method. Time will probably not permit you to use the entire outline as an experiment to be written up, but all of it will prove helpful as a demonstration. Caution the class in drawing the diagrams to make them as nearly *exactly* like the magnetic fields indicated by the filings as possible, otherwise there may be a tendency to make hurried scratchy drawings which will fail not only to represent the conditions which exist, but also to impress *any* facts *definitely* upon the student's mind. For instance, the diagrams in No. 60 should indicate clearly that magnetic lines of force never cross, etc.

No. 59.

LAW OF MAGNETIC ATTRACTION AND REPULSION

Materials. — Compass; two bar magnets or two horseshoe magnets (preferably the former).

Method. — I. First explain the compass: that it consists of a magnetized steel needle, the black end of which, called the

north or the north-seeking end, points approximately north; and an aluminum vane at right angles to the magnetized steel needle, which is not magnetic, and which merely indicates the east and west directions when the magnet points north and south. For the demonstration of I, show that the dark end of the compass needle points north; then present to it each end of a bar or a horseshoe magnet in turn, until the class sees plainly that the north pole of the magnet (marked *N*) attracts the light-colored or *S* end of the compass, and vice versa.

II. Place both *N* poles of the bar magnets or horseshoe magnets together, then place *S* and *N* poles together, and again, two *S* poles, until it is clear to the class that unlike poles attract and like poles repel (which is the law of magnetic attraction and repulsion).

No. 60. MAGNETIC FIELDS OF FORCE

Materials. — Iron (Fe) filings; sifter; one bar magnet and two horseshoe magnets, or either two bar magnets or two horseshoe magnets; sheet of paper; two thin books. A quarter of a pound or a pound of Fe filings may be obtained from the apparatus companies for a few cents. The sifter is not absolutely necessary to the experiment, but it assists materially in sifting the filings evenly over the paper, and may be purchased from the companies, likewise, for a few cents.

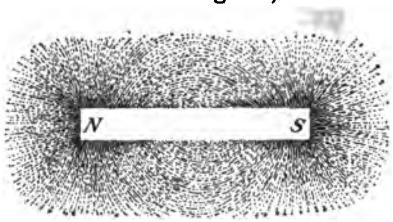


Fig. 52 (S).

Diagram showing the magnetic lines of force surrounding a bar magnet.

Method. — I. Place the bar magnet or the horseshoe magnet between the books, place the paper over the magnet, and sprinkle Fe filings on the paper. Ask questions of the class to bring out the facts that the lines of force in general take a curving path between unlike poles, and that the lines are ap-

parently straight only at a point about ½ in. from each pole end. (See Fig. 52.)

II. Similarly, show the arrangement of magnetic lines of force between two bar magnets or two horseshoe magnets, placed with like poles opposite and near each other (but not touching). (See Fig. 53.)

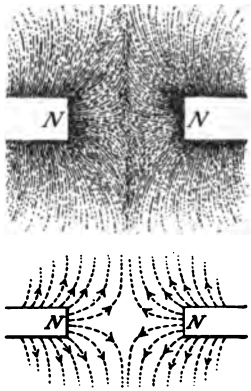


FIG. 53 (S).

Diagram showing the magnetic lines of force between like poles.

III. Similarly, show the arrangement of magnetic lines of force between two bar magnets or two horseshoe magnets, placed with unlike poles opposite and near (but not touching) each other. (See Fig. 54.) The class should note for themselves and indicate in their diagrams that in II the lines of force branch away from like poles, while in III the lines take as direct a path as possible between unlike poles.

Answers. —**1.** Hold the compass above the sheet of paper; if the black end of the needle (the *N* pole) is attracted, the attraction indicates that the *S* pole of the magnet under the paper is near the compass; if the *N* pole of the compass is repelled, the presence of the *N* pole of the hidden magnet is indicated.

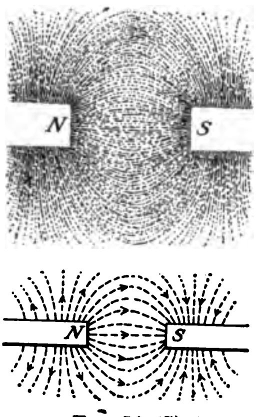


FIG. 54 (S).

Diagram showing the magnetic lines of force between unlike poles.

2. The fact that a nail is attracted by a magnet does not prove the nail to be a magnet, because a magnet will attract, and will be attracted by, an unmagnetized piece of steel or iron.

3. If a nail is repelled by a magnetic pole, the nail is a magnet, for only opposite poles repel each other.

4. Suspend the nail by a string tied around the middle, or float it upon a cork in water. In either case,

if a magnet, it will assume a general north and south position.

5. Only iron and steel are strongly magnetic, but nickel and cobalt and certain magnetic alloys made out of non-magnetic metals (the Heusler alloys) are magnetic to a certain extent. For practical purposes only iron and steel are used. Certain substances, as bismuth and antimony, are slightly repelled by a magnet.

6. The magnetic needle does not point exactly north in most localities, because the location of the magnetic *south* pole, near the earth's geographical *north* pole, is approximately 96° 46′ W. and 70° 5′ N. (Since for convenience we consider the north-seeking pole of a magnet the north pole of the magnet, and since unlike poles attract each other, the earth's magnetic pole, which attracts this north-seeking compass pole, must according to the same convention be the *south* pole.)

7. (1) A magnet always has at least two opposite poles, and may have many poles; a charged body has one sign, or at any rate, it has one sign so much stronger than the other (if it can possess both at the same time, which as yet is a matter of theoretical controversy), that for all practical purposes a single sign can exist alone. (2) Only iron and steel can be strongly magnetized; any substance is capable of receiving a charge. (3) A charge may be conducted; magnetism cannot. (4) Magnetism exists throughout the magnet, magnetic phenomena being assumed to be due to a certain molecular arrangement throughout the magnet; an electrostatic charge is only on the surface of the charged body.

No. 61. THE SIMPLE VOLTAIC CELL

Materials. — Tumbler; compass; water; sulphuric acid (H_2SO_4) or hydrochloric acid (HCl); strip of copper (Cu) and another of zinc (Zn) 5 in. long by 1 in. wide (these can be cut out of sheets of Cu and Zn); connecting wire, about 3 ft. long. A porcelain cap costing about fifty cents is very handy

for connecting the wires to the strips, but is not absolutely essential. A student's demonstration cell complete with cap, strips, and tumbler can be bought for about ten cents more than the cap alone.

Method. — Fill the tumbler about half full of water, and add from $\frac{1}{20}$ to $\frac{1}{50}$ as much H_2SO_4 or HCl. Attach firmly to the metal strips the wires, from which the insulation has been carefully stripped. If the cap is not used, this may be done by wrapping the bare wire-ends about the strips, so that firm contact is made.

CAUTION: *If H_2SO_4 is used, be sure to add the* acid to *the water and* not *water to the acid, to avoid the probability of an explosion and consequent scattering of the acid.*

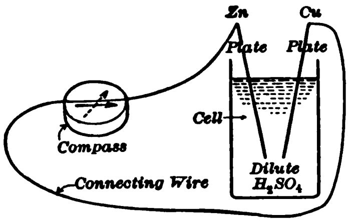


FIG. 55 (S).

Place the compass upon the table, and when the needle has come to rest, stretch the wire over the compass face, so that it runs north and south exactly over the compass needle. Call the students' attention to the fact that the compass remains quiet when no current is flowing. Plunge both metal strips into the tumbler of dilute acid, but do not let the strips touch, and do not remove the connecting wire from its position over the compass needle. Call attention to the needle, which will immediately swing to one side, indicating a flow of current through the circuit. Call attention to the evolution of gas bubbles from the Cu strip, as a further indication of the flow of current, besides the behavior of the needle. Explain that the bubbles will rise from the Zn plate when the current is not flowing in the circuit, but that they will not rise from the Cu strip except when the circuit is complete. Remove the end of the connecting wire from one of the strips, calling attention to the behavior of the compass needle (which immediately swings back to the north and south position which it had before the circuit was completed) and to the evolution of bubbles from the

Zn plate. The class should be able, unassisted, to infer that the cell consists of the two *different metals* immersed in the dilute acid, and that the current flows only when the circuit is complete.

No. 62. THE ELECTROMAGNET

Materials. — Same as in No. 60, with the addition of a bar magnet or horseshoe magnet.

Method. — Wind the middle of the connecting wire around a pencil or penholder until you have a closely wound coil several inches long. Place the compass upon the table, and present both poles of the magnet to the compass until the class has had an opportunity to see the attraction of the magnet for the compass. Then remove the magnet to a distance of several feet from the compass. Without placing the metals in the dilute acid, present the ends of the coil to the compass. They will have no influence upon the needle. Plunge the metals in the acid and, with the circuit complete, present the ends of the coil in turn to the compass, until the class has had an opportunity to observe that the coil now attracts the compass just as the magnet did. With the coil near the compass, break the circuit by removing one of the ends of the connecting wire from the Zn or Cu as above. The compass will no longer be influenced by the coil. The students will be able, unassisted, to infer that a coil through which current is flowing becomes a magnet.

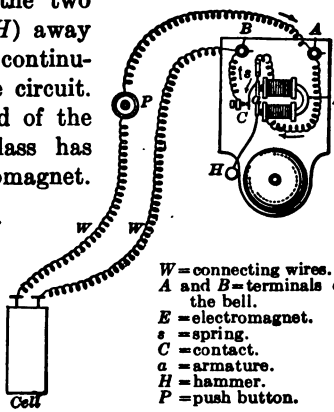
No. 63. THE ELECTRIC BELL

This experiment will prove difficult for the average class, but will be popular with a class (particularly of boys) of more than average ability.

Materials. — Cell as in the two preceding experiments, or better, a dry cell; electric bell from which the iron box has been removed (one costs about forty or fifty cents); connecting wires; compass; push button or knife switch and small screw-

driver. (The two last articles are not essential, as the bared ends of the wires can be touched when it is desired to ring the bell.)

Method. — Connect up the circuit as indicated in Fig. 56, but if you have no push button, leave the two corresponding wire-ends apart. Alternately touch these wires together and pull them apart, showing that the bell rings only when the circuit is complete. Connect the two wires and hold the hammer (H) away from the gong. This makes a continuous flow of current through the circuit. Hold the compass near each end of the electromagnet (E) until the class has clearly seen that E is an electromagnet. Now hold H against the gong, and again hold the compass near both ends of E. The attraction will be much less strong. Explain that the reason there is any attraction at all is that the iron core of the electromagnet retains some of the magnetism, — enough to attract the compass. Call attention to the fact that a is iron, which is attracted by E, but that as soon as a leaves the contact (C), the current ceases to flow through E. The strength of E, therefore, becomes less, so that the spring (s) pulls a back again against C. Thereupon, since the circuit is again complete, a is again pulled over; the circuit is again broken, and so on.



W = connecting wires.
A and B = terminals of the bell.
E = electromagnet.
s = spring.
C = contact.
a = armature.
H = hammer.
P = push button.

FIG. 56 (S).

The student should not be required to reason these things out for himself, as it is probably too much to expect of members of an elementary class. He should be expected to state for his conclusions only: that, (1 and 2) when the circuit is *complete*, the electromagnet attracts the armature toward it; but that, (3) as soon as a leaves C, the circuit is broken, and E loses enough of its strength, so that a is again brought back by the spring (s) to C.

Answers. — **1.** To complete the circuit.

2. When the circuit is completed at the push button, only the exhaustion of the cell or the breaking of the circuit at some other place will cause the bell to cease ringing.

3. Dynamo, motor, telegraph sounder, telegraph receiver, lifting-magnet, etc.

4. This question may be added very successfully as another experiment.

Materials. — Three knife switches or push buttons; screw driver; connecting wire; bell; dry cell. Figure 57 shows how the connections should be made.

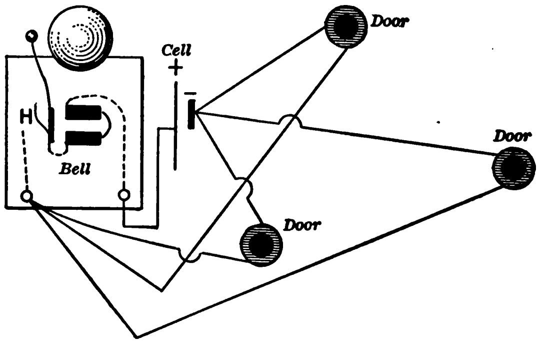


FIG. 57 (T).

Explanation. — One wire from one terminal of the bell serves for all the push buttons; the wires connecting the push buttons with the other terminal of the bell and of the cell must be in parallel with each other, *i.e.* so that the pushing of any one of the three buttons results in closing the circuit. In electricity, "parallel" does not mean wires equidistant from each other at all points, as in geometry, but simply that the wires have their ends attached to the same points in the circuit.

5. This question may be added very successfully as another experiment.

Materials. — Two bells; two knife switches or push buttons;

connecting wire; screw driver; dry cell. Figure 58 shows how the connections should be made.

Explanation. — Both bells are connected in series with the plus terminal of the cell, and the minus terminal of the cell is connected by a separate circuit through each push button to the other terminal of the first bell. (The two push buttons are connected in parallel. See explanation under preceding question.)

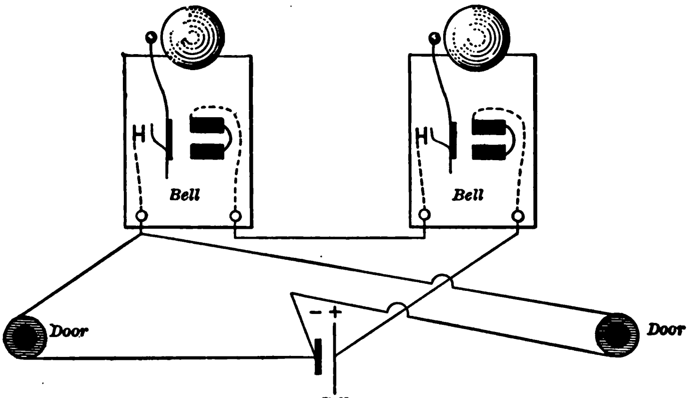


FIG. 58 (T).

No. 64. GAS AND ELECTRIC METERS

Materials. — Dial faces of electric and gas meters; compasses.

Method. — Explain that to read a gas or electric meter we begin at the left and read toward the right, and that it requires one *complete* revolution of each dial to register the number printed at the top of that dial. For instance, if the indicator is between the 5 and the 6 on the dial above which 10,000 is printed, the reading is 5,000 for that dial, not 50,000, since the pointer must travel entirely around the dial in order to register the number at the top, in this case, 10,000. The reading taken is the smaller of the two digits between which the pointer rests.

If, for example, the pointer lacks only a very little of being directly over a digit, for instance 9, on the ten-thousand dial, the reading would be 8000 for *that* dial; but since the pointer of the next dial to the right of the ten-thousand dial would probably be nearly around to the top, the reading of both dials together would be *nearly* 9000. It would not be *quite* 9000, however, until the hands of both dials have made the complete circuit. The same principle holds for the electric meter as well. See Figs. 59 and 60.

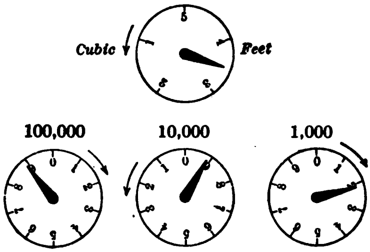


FIG. 59 (S).
Dial reading 89,200 cu. ft.

Place the indicators at various positions and let the class read the meters until each is able to make correct readings. It is well to allow free examination of the dial faces while the students are writing up the experiment and drawing their diagrams. The students may be interested in the gearing system of the meter, by which, for instance, the wheel to which the hundred dial is attached makes ten revolutions while the wheel to which the thousand dial is attached makes one.

Answers. — 1. Probably 99,900, or 9900.

2. Much time is saved in reading the meters and computing the bills, for if a person overpays one month, he underpays the next, since the amount used is computed by subtracting the present reading from that of the previous month.

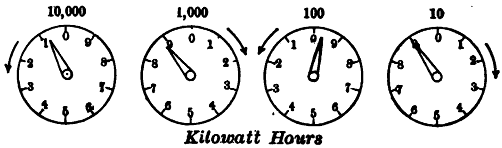


FIG. 60 (S).
Dial reading 899 K. W. hr.

3. The amount consumed during April would be the difference between the two months' readings, or

$$87{,}200 - 85{,}400 = 1800 \text{ cu. ft.}$$
$$18 \times \$.10 = \$1.80$$
$$5\% \text{ of } \$1.80 = \$\ .09$$
$$\$1.71, \text{ amount of bill}$$

4. Probably 9999, or 999.

5. As in Answer 3 above, the amount consumed during April is the difference between the March and April readings:

$$723 - 689 = 34 \text{ K. W. hr.}$$
$$10 \text{ K. W. hr., at } \$.09 = \$\ .90$$
$$10 \text{ K. W. hr., at } \$.07 = \$\ .70$$
$$14 \text{ K. W. hr., at } \$.05 = \$.70$$
$$\$2.30$$
$$5\% \text{ of } \$2.30 = .11$$
$$\$2.19, \text{ amount of bill}$$

6. Boiling a thing rapidly does not make it any hotter, and is therefore a waste of gas unless it is desired to boil something down. Then the greater heat of the burner turned full on evaporates the liquid more rapidly.

7. The simmerer is intended just for this purpose, to keep things boiling slowly, thus permitting greater economy of fuel. But if the boiling food is thick, *i.e.* has not much water in it, it must be stirred frequently to prevent burning, since the heat is concentrated in one small spot on the bottom of the vessel.

8. Light a burner, and note the number of seconds it takes to burn 1 cu. ft., as indicated by the test dial, which is the small dial at the top of the dial face. Remember that the digit at the top of the test dial registers the consumption for one complete revolution of the test dial hand. For instance, suppose it takes a minute and a half to burn 1 cu. ft. of gas. Then, since there are 3600 sec. in 1 hr. $90:3600 = 1:x$; $3600 = 90x$; $x = 40$ cu. ft., which is the consumption of that burner per hour. Similarly, the gas consumption of each burner may be easily computed by proportion. The value of such a table is that it enables the cook to economize gas by placing slow-cooking foods over the burners that consume least gas. But

this should be done only after things have been brought to a boil, for there is no economy in bringing things to a boil on the smaller burners, since the amount of heat required is the same no matter what burner is used, and there is a waste of time in thus using a small burner.

No. 65. PHYSICAL CHANGE

Materials. — Burner; common table salt ($NaCl$); water (H_2O); support stand; evaporating dish; glass rod or piece of glass tubing.

Method. — I. First let several of the students taste the salt to be sure what it is, then dissolve a pinch or so of it in the water, in the evaporating dish. When the salt has dissolved, evaporate the solution to dryness. Use as little water as possible in the first place, as the less water you use, the sooner the evaporation takes place. Call attention to the white residue which results from the evaporation, and then, moistening the end of the glass tube or rod so that it will take up a little of this residue, again allow one of the class to taste the substance. He will, of course, pronounce it to be salt.

II. Heat the glass rod over the flame till it becomes red-hot, and melted on the end; then allow it to cool. The class should be able, unassisted, to conclude that since the salt and the glass did not lose their identity as salt and glass, a physical change is one in which the identity of a substance is not destroyed.

No. 66. CHEMICAL CHANGE

Materials. — Match, evaporating dish; dilute hydrochloric acid (HCl) or dilute nitric acid (HNO_3) or dilute sulphuric acid (H_2SO_4); a few small marble or limestone chips ($CaCO_3$) or tablespoonful of soda (Na_2CO_3); burner; support stand.

Method. — Place the marble chips in a clean evaporating dish and add a *small* amount of the dilute acid, calling attention to the effervescent action.

CAUTION: *If you dilute the sulphuric acid, be sure to* add *the* acid to *the* water, *and* not *the water to the acid.*

When most of the marble, or all of it, has been dissolved, evaporate the resulting liquid to dryness over the flame. Call attention to the resulting white residue. Cool the dish, then add again a little of the acid, calling attention to its failure now to cause effervescence, as it did before. Call attention to the match before and after burning it. The class should be able, unassisted, to infer that, since the marble and the match lost their identity as marble and wood (which was obvious in the first case when the resulting powder failed to effervesce as the original had) and since the wood ash from the burned match was obviously not the same as the wood, a chemical change is one in which a substance loses its identity.

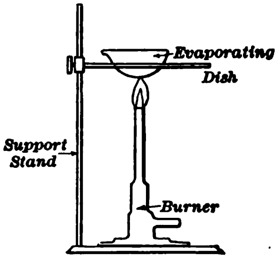


FIG. 61 (S).

Answer. — Physical: melting of ice, crushing of rock, magnetizing of iron; chemical: burning of candle grease, exploding of gunpowder, souring of milk, rusting of iron, digesting of food, the changes which inspired air undergoes.

No. 67. PREPARATION AND STUDY OF OXYGEN (O)

Materials. — Burner; *chemically pure* potassium chlorate ($KClO_3$); *chemically pure* manganese dioxide (MnO_2); support stand; test tube; one-hole rubber stopper; rubber delivery tube several feet long; pneumatic trough or dishpan; jars, tumblers, or wide-mouth bottles; two pieces of glass tubing 2 in. long; water. 5 or 10 g. mercuric oxide (HgO) may be used in place of the $KClO_3$ and MnO_2, as also may sodium peroxide (Na_2O_2), which is sold in tablets as "Oxone."

Method. — Mix equal parts of MnO_2 and $KClO_3$, and place them in the test tube. Fit into the rubber stopper a piece of glass tubing 2 in. long, and insert the stopper in the test tube. The fit-

ting would have to be done before the stopper is inserted in the tube. Connect the rubber tubing to this glass tube, for a delivery tube, placing in the end of this tube another piece of glass tubing. (See Fig. 62.) Place the test tube in a support stand. Fill the pneumatic trough with water, and in it invert the bottles full of water. When the class is assembled, explain what you have done, then apply a small flame to the tube, playing the flame over all parts of the mixture, for if the heat is all applied to the chemicals in the bottom of the tube, the O may generate fast enough to produce a small explosion. Place the end of the delivery tube in the water in the pneumatic trough,

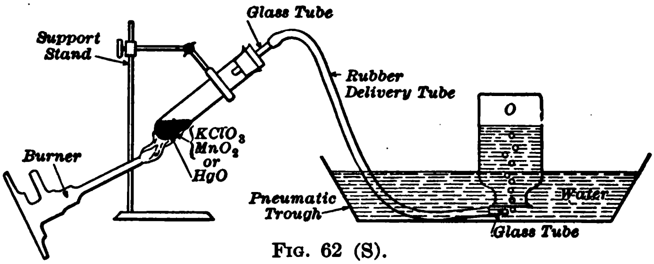


FIG. 62 (S).

and when the gas has been evolving for a minute or so, to drive out all the air, place the end of the glass tubing in the delivery tube under one of the bottles. Call attention to the displacement of the water by the gas. When the bottle is entirely full, place one of the glass plates over the mouth to hold the gas in and remove the jar of O from the pneumatic trough. Collect three or four bottles of the gas. If you use HgO instead of the above mixture of $KClO_3$ and MnO_2, simply put it in the test tube, arrange the apparatus in exactly the same way, and generate and collect the gas as before.

If you use Na_2O_2, or Oxone, arrange the apparatus as in Fig. 63, using a thistle tube provided with a stopcock and allowing the water to drop upon the Na_2O_2, *a drop at a time*. This enables you better than either of the other methods to regulate the quantity of O produced. The students will be able, unassisted, to conclude that O is a colorless gas, less dense than

water, since it displaced the water in the bottles. It weighed less than the same volume of water and hence was pushed up by the greater pressure of the water. CAUTION: In pushing a glass tube through a rubber stopper, grasp the tube *as near the stopper end as possible* and force only a little tubing into the hole at a time, turning the tubing meanwhile. If necessary, wet the rim of the hole in the stopper. The test tube containing $KClO_3$ and MnO_2 may be cleaned with warm water, when it has cooled off. Do not throw the test tube cleanings into the sink. If you have generated the O by either of the two last methods given above, you will need to tell the class how to label their diagrams. (See Figs. 62 and 63.)

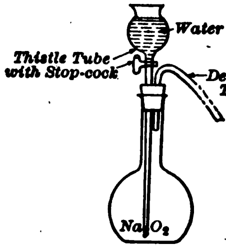


FIG. 63 (S).

No. 68.

COMBUSTION AND COMBUSTIBILITY TESTS FOR OXYGEN (O)

Materials. — Several bottles of O; glass plates; splint; picture wire; sulphur (S); file or piece of heavier wire.

Method. — Collect several bottles of O, and, placing a glass plate over the mouth of each inverted bottle when it is full, set it upright outside the trough. It may be well to allow the class to take rough notes on each test as you perform it, so that they will not get the different tests confused in writing up. Make the following tests in order:

I. Light a splint (shaving) of wood, blow it out, and then, removing the glass cover just enough to admit the glowing splint, thrust it into a bottle of O. When it ignites, blow it out and repeat.

II. Into another bottle of O, drop a piece of S the size of a pea. Heat the handle end of the file or heat the heavy wire and touch the hot end to the S. The S will burn with a brilliant violet flame.

III. Heat the end of the picture wire in the burner, then dip it into S until a small ball of S has melted and adhered to the wire. Ignite this S, and as before, pushing the glass cover aside just enough to admit the wire, thrust the burning S into the jar. The wire will ignite and burn brilliantly, though you may have to try with more than one jar before being successful. The class will be able to conclude that O is not combustible since it does not burn, but that it is a supporter of combustion since these different things burned in it.

Answers. — **1.** A glowing splint will ignite in the O, but not in the air.

2. More O is supplied to the flame, making combustion more rapid.

3. More vigorously, since O is a much better supporter of combustion than is air.

4. If the air were all O, the frames of iron-framed buildings would not be fireproof, since Fe burns in O.

5. About 20%.

6. The air and the O are of so nearly the same density that diffusion would take place rapidly, making tests unsatisfactory.

7. The burning S raised the Fe to its *kindling point*, the temperature at which a thing takes fire.

8. Essential for respiration of animals; an essential constituent of plant foods, such as starch and carbohydrates, etc.; makes combustion possible.

9. Fires once started could not be extinguished; animals could not live long because of the overstimulation; plants could not live in an atmosphere of pure O.

No. 69.

PREPARATION AND STUDY OF HYDROGEN (H)

Materials. — Bits of zinc (Zn), or powdered iron (Fe), (Fe gives a more rapid evolution of H, but is more expensive); dilute hydrochloric acid (HCl); delivery tube drawn to fine point (see Introduction); support stand; small test tube or bottle; matches; generator, as in Fig. 64. If pure Zn and

pure acid are used, add a little copper sulphate ($CuSO_4$, blue vitriol) solution to the generator to start the action.

Method. — The experiment on H can be performed with perfect safety provided the following precautions are taken. *Before adding the acid, wrap a cloth around the generator*, to prevent danger from flying glass if there should be an explosion. There will be practically no danger of an explosion if *all flame is kept away from the delivery tube until after the H has been tested as indicated below, and found pure, and if the stopper of the generator is perfectly tight.* It is well, however, to observe both precautions. Do not attempt to collect any of the gas from

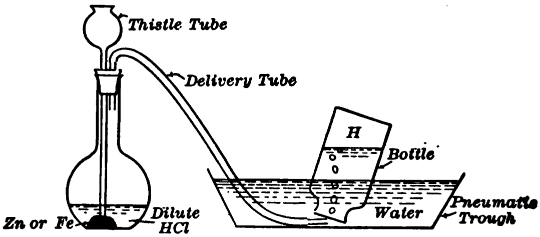


FIG. 64 (S).

the delivery tube for a few minutes, until all the air has been expelled from the generator and delivery tube. Then test the gas as follows, before collecting a jar of it.

Fill the small test tube or bottle with water, and invert it in the pneumatic trough. Fill it with the gas from the delivery tube by displacing the water. When it is full, keeping the mouth of the delivery tube under water, quickly bring a lighted match to the mouth of the test tube, still held upside down (for the H is so much less dense than air, that it would quickly escape if the mouth of the test tube were held up). If the H is still impure, that is, mixed with air, there will be a slight whistling explosion; if pure, the H will burn up in the test tube without any explosion. Keep testing the gas at intervals of a minute or so, until it is proved to be pure. Make at least one more test after there has ceased to be any explosion at the mouth of the test tube, then collect two bottles of H, cover the jars with

glass plates, and set aside the H to be used in the following experiment. The class will be able to conclude unassisted that H under ordinary conditions is a colorless gas, and that it is less dense than water, since it displaces the water.

No. 70. COMBUSTION AND COMBUSTIBILITY OF HYDROGEN (H)

Materials. — H generator; splint (shaving) of wood; dry test tube.

Method. — Have the generator all ready before class. After you are assured of the purity of the H as tested in No. 69, collect a bottle of the gas, and keeping it bottom up, plunge a burning splint *into* it. The splint will be extinguished, but the H will take fire at the mouth of the tube and burn with a quiet flame. Light the pure H as it escapes from the small end of the delivery tube. Hold the dry test tube over the flame for a moment until it is evident that moisture is collecting on the sides of the tube. From these demonstrations the class should be able, unassisted, to infer that H is combustible, but not a supporter of combustion. Many other interesting phenomena may be shown in connection with H, as, for instance, blowing bubbles of strong soap and glycerine solution from a clay pipe placed in the end of the delivery tube from the H generator. When detached from the bowl of the pipe, they will be forced up in the air like a balloon, and will burn if touched with a lighted match or splint.

Another possible demonstration is blowing bubbles of H upon the surface of a strong soap and glycerine solution placed preferably in an iron vessel. When touched with a lighted splint, they will explode with great violence. If you perform this last experiment, keep the generator at a considerable distance from the bubbles when you explode them, light the bubbles from the end of a splint long enough for you to stand several feet away, and stand upon tip-toe with mouth open, to equalize the pressure differences caused by the detonation.

To avoid needless confusion for the student, these last two

demonstrations had better be made as another experiment, performed after the combustion and combustibility tests are completed and written up.

Answers. — **1.** The H united violently with the O in the air, when heat was furnished, forming water (H_2O). This was a chemical change, since a new substance, having entirely different properties, was produced from the old ones (H and O having entirely lost their identity as H and O).

2. To prevent the escape of H through the thistle tube instead of through the delivery tube.

3. Answered in Method of No. 69.

4. H is less dense than air.

5. A glowing splint will burst into flame in O; H will burn if a flaming match is applied; a burning splint will continue to burn in air, but the flame will be extinguished in CO_2 and N; a little limewater added to the two now known to contain either CO_2 or N will turn milky when shaken around in the jar of CO_2, but not in the N.

6. Tremendous explosions would result as soon as any flames were brought into a vicinity where there were great quantities of free H and O.

No. 71. ELECTROLYSIS OF WATER

This experiment is successful qualitatively only; it is best not to attempt to work out the quantitative relation between the oxygen and hydrogen produced, as the quantities will not indicate the correct proportion with any degree of accuracy.

Materials. — Several dry cells or other source of *direct* current; connecting wire (don't use *very* fine wire, as its increased resistance, resulting from its small diameter, will cut down the current); electrolysis of water apparatus; water to which has been added two or three drops of any kind of acid. An electrolysis of water apparatus may be improvised out of the bared ends of the terminal wires and two test tubes thus: fill the test tubes with water and invert them in a pan of acid-

ulated water; bend the wires so that the ends from the battery of cells come inside the tubes. (See Fig. 65.) This apparatus will merely show that water can be decomposed into two gases, but No. 72 cannot be performed with so crude a setup. A considerable fraction of the gases produced will probably be redissolved in the water, making impossible accurate conclusions regarding the relative quantities of O and H produced. Serviceable electrolysis of water apparatus can be bought from the apparatus companies for from $2 to $7.50, but one with graduated arms provided with stopcock or some other device by which the evolved gases may be collected (see Fig. 66) will prove more satisfactory than a cheaper one. If the electrolysis of water apparatus is used, a support stand

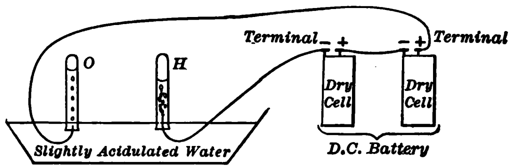


FIG. 65 (S).

is necessary for setting it up. Rest the glass tube connecting the two arms of the apparatus upon a support, and merely *hold* the tube *in place* with burette clamps; do not attempt to support the weight of the apparatus by clamping it tightly with burette clamps.

Method. — Connect several dry cells in *series;* that is, connect the carbon terminal of the first cell (the one in the middle of the cell) to the zinc terminal of the next cell (the one at the side of the cell), and so on, finally connecting the two terminals of the electrolysis apparatus, respectively, to the zinc terminal of the first cell and the carbon terminal of the last. Use short pieces of wire and strip the cloth insulation from the ends, before making the connections with the cell terminals, as no current will flow unless there is metal contact throughout the circuit. When you pour the acidulated water into the apparatus, leave the stopcocks open until the water has filled the tubes to a point a very little above the cocks. The apparatus should all be set up and the current allowed to flow for an hour

or so before class. The students will be able, unassisted, to infer that two substances, both gases, are produced when a direct current of electricity is sent through water, and that, therefore, water is composed of two gases.

No. 72.
TO IDENTIFY PRODUCTS OBTAINED FROM THE ELECTROLYSIS OF WATER

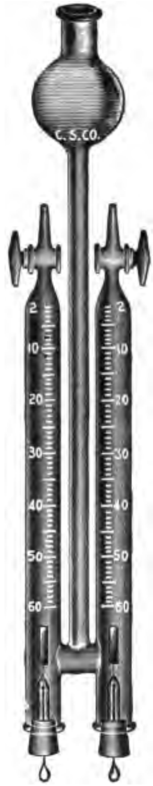


FIG. 66 (T).

Great care must be exercised in performing this experiment, to prevent losing the gas without showing what it is. The experiment will not be understood unless it has been preceded by the experiments on oxygen and hydrogen, as otherwise the class will have no previous experience upon which to base their conclusions.

Materials. — Electrolysis of water apparatus, set up and connected with direct current as indicated in the preceding experiment; splint; match; sheet of white paper.

Method. — The current should be allowed to flow for several hours before the class assembles, or until 25 c. c. or 30 c. c. of oxygen (the less abundant gas produced) have been generated. Before the class assembles, *very carefully* open the cocks, just enough to expel all the water which is above the gases in the arms. When the class is assembled, light the splint and blow it out, until only a glowing coal remains. Hold this over the arm containing the smaller amount of gas (the oxygen), and *cautiously* turn on the gas — a *very* little of it, else it will all escape before the class has had an opportunity to note its presence by the fact that the glowing splint lights. Hold a lighted match over the arm containing the greater amount of gas (the hydrogen) and carefully turn on a *very* little of the gas. It will ignite and burn, but as

the flame is nearly colorless, its presence can only be indicated to the class by holding the sheet of paper behind it. Do not let the H burn any longer than necessary, as the intense heat of the hydrogen flame may crack the tip of the tube.

Invite *very close attention* to both parts of the experiments, else the gases will all be used up before the whole class sees the tests. By referring to the O and H experiments (67 and 69), the class should be able, unassisted, to infer that the greater quantity of gas is H, because it burns, and the smaller quantity, O, because it causes a glowing splint to burn. Of course such conclusions based upon such scanty data would be justified nowhere except in a very elementary course, and only then when it is understood that the two gases are among those already studied in the course. In the diagram allow the student to use the conventional symbols* for a D. C. (direct current) battery, and see that he has the wire marked plus attached to the oxygen arm of the apparatus, and the minus terminal attached to the hydrogen arm of the apparatus. It may prove inadvisable in so elementary a course to explain why this must be done, as such discussion, involving the electrolytic hypothesis, belongs in a more advanced course in physics and chemistry.

* Symbols for D. C. battery.

Answers. — **1.** Electrolysis.

2. Electrolysis of water.

3. Absolutely pure water cannot be electrolyzed.

No. 73. PREPARATION AND STUDY OF NITROGEN

Materials. — Pan of water or pneumatic trough; piece of yellow or red phosphorus (P), the size of a small pea; crucible or small disk of cork; wide-mouthed bottle or jar; file or piece of wire; glass plate; knife; forceps; match; burner.

CAUTION: *Yellow* P takes fire when exposed for a short time to the action of the air at room temperature, and produces very serious burns. The heat of the fingers is often sufficient to

raise yellow P to its kindling point. To *avoid all danger*, keep yellow P covered with *water all the time*, and *do not handle* the yellow P *with the fingers*, but *use the forceps* to *hold, handle*, and *remove* the piece you cut off. *Red* P can be handled without danger, and it does not take fire at ordinary temperatures. Avoid inhaling any of the fumes of the burning P.

Method. — Have ready the bottle or jar, then cut off the piece of yellow P, and place it (or a little red P) upon the cork disk floating in the water. It is perhaps more convenient to place the P in a small porcelain crucible floating in the water because the cork burns and chars somewhat. Touch the red-hot handle end of the file or the wire to the P, and *immediately* place the bottle, mouth downward, over the cork and burning P, holding the hand upon the bottle. (See Fig. 67.) Call attention to the spluttering flame and dense white fumes (phosphorus pentoxide, P_2O_5), which dissolve in the water, and to the fact that the water is forced up a little distance into the bottle. It is perhaps best to give no more of the chemistry involved than that P combines with the O in the air inside the bottle to form the white powder which dissolves in the water, leaving only N in the bottle. It is not necessary to mention the presence in air of the other gases, such as argon, ammonia, and carbon dioxide, of which only very small portions are present. Let the students draw the figure while the fumes in the bottle are clearing, then place a glass plate over the mouth of the bottle under water and remove the bottle from the pan, retaining the gas for the following experiment. The bottle will have some water and the cork or crucible in the bottom of it below the N. The class will infer, unassisted, that N is a colorless gas, less dense than water, because it remains above the water in the bottle.

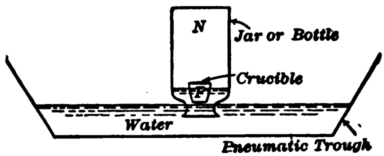


FIG. 67 (S).

No. 73. PREPARATION OF NITROGEN (N) (Alternative)

This method is easier and more satisfactory from the instructor's point of view, though less spectacular.

Materials. — 3 g. of sodium nitrite ($NaNO_2$); 3 g. of ammonium chloride (NH_4Cl); 100 c. c., water (H_2O); burner; Florence flask fitted with one-hole rubber stopper and delivery tube, such as was used in No. 67 for collecting O; pneumatic trough or pan; wide-mouth bottle; glass plate.

Method. — Place the $NaNO_2$ and NH_4Cl in the flask, add the water, insert the stopper, and apply gentle heat. Collect the gas by the method of water displacement explained in No. 67. Allow the gas to generate a few moments before you collect any of it, in order to be sure that the air has all been swept out of the generator and delivery tube.

No. 74. COMBUSTIBILITY TESTS FOR NITROGEN (N)

Materials. — Match; splint; jar of N.

Method. — Light the wooden splint and, removing the cover just enough from the mouth of the bottle to introduce the flame, thrust the splint down into the gas. The students will be able to infer from the fact that the flame is immediately extinguished and the gas fails to light, that N is neither combustible nor a supporter of combustion.

Answers. — **1.** Four-fifths.

2. If all the air were O, life would be impossible for the reasons given in Answer 9, No. 68 (Oxygen). N is indispensable to plants, being in fact a necessary part of all living cells, plant and animal.

3. See Answer 5, No. 70 (Hydrogen). (Require only such part of this answer, of course, as involves the gases already studied.)

4. P unites with O to form solid phosphorus pentoxide (P_2O_5), the substance which appeared as dense white fumes. This substance dissolves in water, forming phosphoric acid.

5. When the O is removed from the air, as it is in this experiment, the pressure on the surface of the water in the bottle is lowered, because now there is only about four-fifths as much gas in this space as formerly. The greater atmospheric pressure upon the water in the pneumatic trough outside, therefore, pushes water up into the bottle until the pressures within and without are again equal.

6. Oxygen (O), carbon dioxide (CO_2), argon (A). These are the principal gases, though there is also a trace of ammonia (NH_3), as well as minute traces of helium (He), neon (Ne), xenon (Xe), and krypton (Kr) in the air. Dust and water vapor are important components of the air.

No. 75.

PREPARATION AND STUDY OF CARBON DIOXIDE (CO_2)

Materials. — Carbon dioxide generator arranged with funnel tube or thistle tube and delivery tube, as in Fig. 68; marble or limestone chips; wide-mouth bottle; beaker or tumbler; glass plate; dilute hydrochloric acid (HCl). Since CO_2 is formed by the action of any acid upon any carbonate, vinegar and soda, chemical calcium carbonate, or broken clam shells may be substituted for HCl and marble chips.

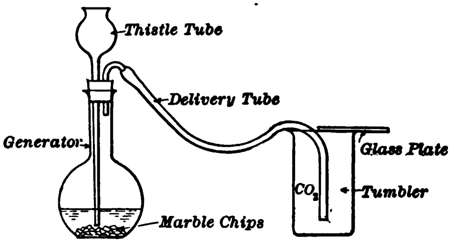


FIG. 68 (S).

Method. — Place the small marble chips or the soda in the generator (a Florence flask, or an Erlenmeyer flask, or a large test tube may be used), and if you have only concentrated HCl in the laboratory, add a little water before adding the acid through the thistle tube. After the effervescence has continued for a few moments — long enough to expel the air from the generator and delivery tube, place the end of the delivery

tube in the tumbler, keeping the glass plate almost covering the mouth of the tumbler, to prevent diffusion of the CO_2 with the air. (See Fig. 68.) After a few moments remove the delivery tube from the tumbler, placing the cover over the tumbler, and putting the latter aside to use in the following experiment. The class should be able, unassisted, to infer that CO_2 is a colorless gas, more dense than air, since it displaced the air from the tumbler.

No. 76.
COMBUSTION AND COMBUSTIBILITY OF CARBON DIOXIDE (CO_2)

Materials. — The tumbler of CO_2, generated in the preceding experiment; splint; match.

Method. — Place the lighted splint in the jar of CO_2. The class will be able to conclude unassisted that CO_2 is neither combustible nor a supporter of combustion, since it neither burns nor permits a combustible substance, such as wood, to burn in it.

No. 77.
EFFECTS OF CARBONIC ACID UPON LIMESTONE

This experiment is added to afford a better correlation with the physiographical applications of CO_2.

Materials. — CO_2 generator as used in No. 75; test tube or bottle half filled with clear limewater. Limewater may be made by dissolving calcium oxide or calcium hydroxide (lime) in water.

Method. — Allow the CO_2 to bubble through the limewater; explain that the milky precipitate formed is calcium carbonate ($CaCO_3$) or limestone. But if the CO_2 is allowed to bubble through the limewater for a longer time, finally the calcium carbonate or limestone formed will redissolve, and the liquid again become clear. The class will infer that when a little carbonic acid comes in contact with limewater, limestone is formed; and that strong carbonic acid dissolves this limestone or marble.

Answers. — **1.** CO_2.

2. CO_2 is an efficient fire extinguisher because it does not support combustion. Near the floor because, being denser than air, it would fall to the floor, smothering the fire there. Most chemical fire extinguishers depend for their action upon the rapid generation of CO_2.

3. (1) CO_2 in the breath smothers the fire, *i.e.* does not support the combustion of the match; (2) some of the heat of the burning match is *convected* away by the violence of the blowing, with the result that the rest of the match cannot be raised to the kindling point of wood.

4. See Answer 5, No. 70.

5. CO_2, partly derived from the oxidation of humus and the action of bacteria upon humus in the soil, and partly derived from the air, combines with ground-water.

6. Carbonic acid percolates through the rock, dissolving the limestone and leaving the cave. Sometimes part of the cave roof falls in, leaving a natural bridge.

7. The pop is charged under considerable pressure, which makes it possible to dissolve much more CO_2 in the water. When the cork is removed and therefore the pressure is lessened, this excess CO_2 is no longer held in solution, and bubbles out.

8. See Answers 1 and 8, No. 84.

9. Calcareous tufa, and travertine.

10. If, when a drop of the acid is added to the rock, effervescent action results, the rock is a carbonate.

No. 78. TEST FOR ACID, BASE, AND SALT

Materials. — For the acid: hydrochloric acid (HCl) diluted, or vinegar; for the base: soda, or borax, or sodium hydroxide; for the salt: common table salt. Three tumblers or beakers; test tubes; glass stirring rod; strips of blue and red litmus paper, or a solution of blue litmus powder or cubes, in water (for the red solution, add a *very little* acid, only a drop or so, to the second portion of the solution), or purple potato or purple cabbage infusion.

This latter is preferable to the litmus solution for the experiment with an elementary class, as it gives one more color change. It may be made by boiling the purple potatoes or the purple cabbage leaves in a granite-ware pan. Do not use an aluminum or metal dish.

Method. — Before class make the acid, base, and salt solutions. If you use the liquid indicators (the litmus solutions or the potato or purple cabbage infusion), have them ready also. If you use the litmus strips, first tell the class what substance is in each tumbler and whether it is an acid, a base, or a salt; then, with the stirring rod, place a drop of each liquid upon red and blue strips of litmus paper. The acid will turn the blue litmus red, but will not affect the red litmus; the base will turn the red litmus blue, but will not affect the blue; the salt will not affect either the red or the blue litmus. Blue litmus paper which has been for a long time in the laboratory turns red or reddish, because of the action of the weak carbonic acid in the air, and may be restored to its original blue color by subjecting it to ammonia fumes. The tests are the same with the litmus papers as with the solutions. If you use the potato or cabbage infusion as an indicator, proceed exactly as with the litmus solution. The acid will turn the lilac-colored infusion red; the base will turn the blue infusion green; the salt will not affect it. The class will be able, unassisted, to infer that if a substance turns blue litmus or purple cabbage infusion red, it is an acid; if it turns the red litmus blue, or the purple cabbage infusion green, it is a base; if it has no effect upon either indicator, it is a salt.

No. 79.
"SWEETENING" SOUR MILK (NEUTRALIZATION)

Materials. — Half pint of sour milk, the sourer, up to the unusable point, the better; soda; teaspoon; glass stirring rod or another spoon; red and blue litmus strips.

Method. — Measure out a level teaspoonful of soda, by heaping the spoon and then running a case knife flatwise across the edges of the spoon, leaving the latter exactly full. Add the

soda a bit at a time to the sour milk, stirring the milk meanwhile and testing it frequently with the blue and red litmus paper, as in No. 78. When neither paper changes color, the milk is neutral. The milk will froth and effervesce during the addition of the soda, and will therefore increase considerably in volume. About a teaspoonful of soda is usually sufficient to neutralize a pint of clabbered milk.

Answers. — 1. One which has no effect upon an indicator such as those used in the experiment, or in other words, a solution which is neither acidic nor basic.

2. To neutralize the acid in them.

3. Soda is sodium carbonate, and whenever any acid is added to any carbonate, carbon dioxide gas is always evolved.

4. The evolution of the carbon dioxide and its subsequent rise through the batter render the cakes porous and light.

5. The acid in the berries curdles the milk.

6. Food containing an excess of soda will be less wholesome, and will taste of the soda; too little soda will leave the food still acidic and sour.

7. Bacteria, in consuming the humus, liberate considerable quantities of carbon dioxide, which combines with soil water to form carbonic acid; other acids are likewise formed in the soil by bacterial action. Whenever the bases in the soil are no longer sufficient to combine with and neutralize the acids, the soil remains acid or "sour." The acidity can be determined by leaching some of the soil; that is, by allowing water to soak through it, then testing this water with an indicator as above.

8. (1) The acids are a waste product of the soil bacteria, and, unless removed, injure the bacteria which produce them; (2) excess of acid in the soil is injurious to the higher plants.

9. Spread finely ground limestone, or land plaster (lime) upon the surface of the ground. Wood ashes, also, will reduce acidity.

No. 80.

REMOVAL OF VARIOUS STAINS FROM CLOTH

Materials. — New blotters; clean white cloths; water. For Method I: hot flatiron; a little grease; piece of black cloth; carbon tetrachloride, which can be bought from any chemical supply house or wholesale drug store, and probably from any small drug store, where it is frequently offered for sale as a patented cleaner under various names.

For Method II: white cloth; grass; flower; denatured alcohol; ammonia.

For Method III: white cloth; rusty nail or other piece of rusty iron; a lemon; salt.

For Method IV: white cloth; milk; boiling water; alcohol; blotter; lemon; salt; strong ammonia; sodium hyposulphite (hypo); choride of lime; vinegar; ink.

For Method V: cloth; paint; carbon tetrachloride; amyl acetate; turpentine.

For Method VI: black cloth; a lemon; dilute ammonia.

Method. — First state that ordinary spots on clothing, which usually are grease spots, may nearly always be removed by rubbing over them a clean white cloth dipped in warm water, or in soapy water, made of a good quality of white laundry soap.

EMPHASIZE STRONGLY: *that no gasoline or benzine should be used in cleaning clothes.* — They are so explosive that the vapor may be ignited by a small flame at a considerable distance. The vapor is so dense that it will flow into a depression in the floor or under it, and unless dispersed by air currents, will remain there for a long time, and can be ignited by a spark struck from a nail in the shoe. The friction of rubbing together silk gloves saturated in gasoline is frequently sufficient to ignite the gasoline.

EMPHASIZE STRONGLY: *that carbon tetrachloride, which is not explosive or inflammable, will do the cleaning work of gasoline and benzine.*

In cleaning colored goods with chemicals, it is best to try the effect upon a small strip of the cloth, before applying the chemi-

cal to the cloth itself, as it may bleach, discolor, or otherwise injure the cloth.

I. Make a grease spot upon the cloth, then moisten a corner of a clean white cloth with carbon tetrachloride, and rub in the same direction across the spot. Do not rub around and around. Also try removing a grease spot by placing blotters above and below it, and placing a hot flatiron upon the top blotter.

II. Stain the cloth with grass or the flower, and remove the stain with a corner of the clean white cloth dipped in alcohol. Ammonia may sometimes be successfully substituted for the alcohol, but it should be rinsed out with water after the stain has been removed.

III. Stain the white cloth with rust, then squeeze lemon juice and rub salt upon the stain. Rinse well in water, and if the stain is not entirely removed, repeat the whole operation.

IV. Since inks are made of so many different chemicals, several methods of removal will probably need to be tried before you are successful. If the stain is still wet, it may sometimes be removed by applying warm alcohol. Place the blotter under the cloth and pour the alcohol through the ink spot. *Do not heat the alcohol over a flame;* heat it by dipping a test tube or other vessel containing a little of it, in hot water. A fresh ink stain may sometimes be removed by pouring boiling water through it. Wash the fresh stain in milk; and if the stain is not removed, apply lemon juice, and rinse thoroughly in water afterward. Strong ammonia will sometimes be effective, but it must be rinsed thoroughly out of the cloth immediately afterwards. Household or commercial chloride of lime or bleaching powder solution, to which have been added a few drops of vinegar, or strong "hypo" solution will frequently be effective, for *white* goods. Dip the spot in the solution, then rinse thoroughly.

V. Carbon tetrachloride or turpentine will usually remove paint stains; but if the stain is an old one, it may need first to be softened by applying amyl acetate. Turpentine must not be applied to silk.

VI. Rub a cloth dipped into weak ammonia upon acid fruit stains.

Answers. — **1.** The hot iron converts the grease to a liquid, and it is then taken up by capillarity, through the capillaries in the blotter.

2. Alcohol is used to dissolve green chlorophyll in No. 109 (Photosynthesis).

3. Red oxide of iron (Fe_2O_3).

4. Because there are so many different kinds of ink, of different chemical compositions, which react with different chemicals.

5. See CAUTION on page 108.

6. Ammonia is a base which neutralizes fruit acid, forming a salt. Sodium hydroxide injures cloth if it is woolen or part woolen.

No. 81. HARMFUL FOOD ADULTERANTS

Materials. — For Method I: sample of milk; a little formaldehyde; stirring rod; hydrochloric acid (HCl); ferric chloride ($FeCl_3$); pan; beaker; casserole or evaporating dish.

For Method II: canned string beans or peas; a very little copper sulphate (blue vitriol — $CuSO_4$) or other soluble copper salt; bright iron nail; beaker; larger cooking vessel.

For Method III: sample of pure baking powder (a high-priced standard brand); a little tincture of logwood; ammonium carbonate [$(NH_4)_2CO_3$]; a little alum; dish or beaker.

For Method IV: some freshly ground lean meat; boric acid; HCl; turmeric paper; evaporating dish.

For Method V: strips of woolen cloth; sodium hydroxide (NaOH) solution (1 g. to 25 c. c. of water); homemade catsup, jam, or jelly; beaker or evaporating dish; warm water; a little of any bright commercial cloth dye; funnel; filter paper.

Method. — I. Pour 5 c. c. of milk into a beaker and stir it with a glass stirring rod, the end of which has been dipped in formaldehyde. Add 5 c. c. of HCl and a drop of dilute ferric chloride solution. Gently rotate the beaker in order to mix the

liquids, then place for five minutes in boiling water. A purple or lavender color is the test for formaldehyde.

II. Mash a spoonful of canned beans or peas and put in a beaker along with a very little $CuSO_4$ solution. Add a little water and a few drops of HCl. Place the bright nail in the beaker, then put the beaker into the larger cooking vessel containing boiling water. Stir constantly while the water boils ten minutes. The nail will receive a copper plate, and will therefore turn dull red.

III. Into a spoonful of the baking powder put a little powdered alum, add 10 c. c. water, 2 c. c. tincture of logwood, and 2 c. c. ammonium carbonate solution. A lavender-blue color, which does not disappear when the mixture is boiled, is the test.

IV. Add a little borax or boric acid to the ground meat. Add a few drops HCl, warm the mixture, and soak some turmeric paper in it. Dry the paper at a moderate heat. The rose-red color on the dried turmeric paper is the test.

V. Boil the woolen strips first in the dilute sodium hydroxide, then in water. This removes the grease from the cloth. Add a very little of the dye to a few c. c. of the catsup, jelly, or whatever it is you want to test, dilute to about a quarter strength, and filter. (See No. 24.) Boil the woolen strips for five minutes in the solution, remove, and wash them thoroughly in warm water. They will be vividly colored. Now repeat the whole process, using a sample of homemade catsup or jelly to which no dye has been added. It also will finally show color in the woolen strips, but the colors will be dull. The students should be impressed with the difference between these legitimate colors and those more vivid ones imparted by the coal-tar dyes.

No. 82.

TO TEST FOR HARMFUL FOOD ADULTERATIONS

The preceding experiment is intended, first to produce the adulteration, and then to show how to detect it. This experiment is to test commercial products, to determine whether or

not they have been so adulterated with harmful adulterants. There are other harmful adulterants than those indicated above, but the tests are too complicated to be included in so elementary a course.

Materials. — Some cheap high-colored samples of food and also some samples of food of the best grades; other materials same as in No. 81.

Method. — Make the tests exactly as described in the preceding experiment. You will probably find few samples which contain adulterants. An interesting further experiment would be to test a number of samples of the same kind of substance, such as baking powders, for instance, to see whether some of them were alum baking powders, which are said to be less desirable than soda and cream of tartar baking powders.

Answers. — **1.** By "food adulterant" is meant anything added either to preserve or to color the product, or anything which is added in place of some of the substance the product is represented as containing, to render it cheaper to manufacture.

2. One runs little risk, or at any rate less risk, of getting adulterated foods from firms which pride themselves upon the purity of their products, and emphasize this fact in their advertisements. This does not mean, however, that no highly advertised food is adulterated.

3. All adulterants are not harmful; some are just as good as the substance they are substituted for, the harm being in this case merely that of misrepresentation (see definition of food adulterant above).

4. Egg shells are porous, and permit the dyes to go through and color the egg white inside. This dye is injurious.

5. Fruit colorings are harmless, while coal-tar dyes are not.

No. 83. STUDY OF SOME TYPICAL MINERALS

Materials. — The following are suggested as a good list of typical minerals to study, though others may be of greater local interest and may be substituted with equal or greater value:

quartz, feldspar, mica (biotite and muscovite), calcite, hornblende, gypsum, halite, hematite, and iron pyrites. Necessary materials are: mineral sets (which, already numbered and described, are obtainable from apparatus companies); knitting needle; magnet; hydrochloric acid (HCl).

Method. — The following qualities will be suggestive of what sort of classifications may be made; all need not be required, but a selection can be made from this list: color, relative hardness, luster, structure, transparency, whether a carbonate or not, whether magnetic or not, cleavage or fracture, uses. The following explanations will need to be made before the class will understand how to test for these various qualities in a sample.

Color: color will of course vary with the samples examined.

Hardness: a mineral may be considered very soft, when it can be scratched with the thumb nail; soft, when it can easily be scratched with steel (a knitting needle or hatpin is a good implement to use for this test); hard, when it can with difficulty be scratched with steel; and very hard, when it cannot be scratched with steel.

Luster: samples may be classified as vitreous, like glass; pearly, like a pearl; greasy, as if the surface were greased; silky, like silk; resinous, like resin; metallic, like a metal surface.

Structure: a mineral may be crystalline or amorphous, porous or compact, uniform in structure or stratified.

Transparency: a mineral is transparent, if objects can easily be distinguished through the sample; translucent, if light can be seen through the sample but objects cannot be distinguished; opaque, if no light can be seen through the sample.

If the sample effervesces when a drop of HCl is placed upon its surface, it is a carbonate.

Few of the minerals will be attracted by a magnet, magnetite or lodestone being an exception.

A sample has cleavage if it breaks along certain planes (you can usually tell from the edges of the sample without

MINERALS

Name	Color	Hardness	Luster	Structure	Transparency	Carbonate	Magnetic	Cleavage or Fracture	Uses
Quartz	Colorless or of various colors depending upon the sample	Very hard	Dull or vitreous depending upon sample	Crystalline	Transparent, translucent, or opaque depending upon sample	No	No	Fracture	Gems, manufacture of glass, porcelain, sandpaper, etc.
Feldspar	White, pink, and rarely brown or green	Very hard	Depends upon sample and angle at which it is viewed	Crystalline	Opaque	No	No	(Two directions) Cleavage	Manufacture of porcelain and chinaware, gems (tourmaline), etc.
Mica	Muscovite (colorless); Biotite (black or green)	Soft	Pearly	Crystalline	Muscovite (isinglass) transparent; Biotite in thin plates only	No	No	(Thin plates) Cleavage	Electrical purposes, in stove and furnace doors, as a lubricant, for decorative purposes, etc.
Calcite	Colorless to white (pure); red, black, blue, yellow, or gray (impure)	Soft	Dull or vitreous depending upon sample	Crystalline	Usually opaque, but depends upon sample	Yes	No	(Three directions) Cleavage	Building stone, cement, quicklime, ornaments, statuary, etc.
Hornblende	Black, white, or light green	Very hard	Depends upon sample	Crystalline	Opaque	No	No	(Two directions) Cleavage	Asbestos, fireproof cloth and curtains, covering for pipes, ornaments (jade), etc.
Gypsum	White, gray, yellow, or red (pure); brown or black (impure)	Soft	Pearly to dull	Crystalline	Transparent or opaque	No	No	(Thin folds) Cleavage	Fertilizer, plaster of Paris, Portland cement, wall plaster, ornaments (alabaster), etc.
Halite	White or gray	Hard	Dull	Crystalline	Opaque	No	No	Depends on sample	Salt, most sodium and chlorine compounds
Hematite	Red, steel gray, or almost black	Soft	Metallic or dull	Crystalline	Opaque	No	No	Cleavage	The most important iron ore
Iron Pyrites	Yellow or brassy	Very hard	Metallic	Crystalline	Opaque	No	No	(Cubes) Cleavage	Manufacture of sulphuric acid, a source of sulphur

breaking it); if it does not break along planes, it has fracture. In so elementary a course it is perhaps unwise to attempt to classify the kind of fracture, into conchoidal, fibrous, striated, etc.

Frequent reference to texts may be encouraged, in connection with this kind of exercise, for the purpose of ascertaining the qualities which the students are unable to determine with certainty for themselves, and for checking their results.

Allow the students to mark off a page in their notebooks, somewhat as on page 114. The number of vertical columns depends on the number of different qualities to be determined.

No. 84. STALACTITES AND STALAGMITES

This experiment requires two or three weeks.

Materials. — Alum; water; two pieces of brass or copper gauze (iron gauze is undesirable, because it rusts); two beakers or tumblers; glass siphon tube drawn to a very fine point; support stand; pin; paraffin.

Method. — Bend a glass siphon tube and draw one end of it to a very fine point (see Introduction). It will probably be impossible to draw the glass to a sufficiently fine point to permit a slow enough drip; but as slow a drip as you please may be secured in the following way. Scrape the fine point of the siphon down the side of a block of paraffin. The paraffin will form a long plug which will completely stop up the siphon. Fill the siphon tube with concentrated alum solution, made by dissolving as much alum as possible in tepid water, and set up the apparatus as indicated in Fig. 69. Then, with the pin, carefully push up against the end of the paraffin plug in the siphon tube, displacing it *just enough* to secure a drop about once a minute. You may have to make several paraffin plugs, before you get just the right-sized opening in the siphon end, but if you fail to do so, push the plug up into the tube; it will rise to the top of the bend, and allow another to be made in the siphon end. The siphon will probably have to be restarted

every morning, as the evaporation of the solution will eventually stop the hole in the tube end. In filling the siphon tube it is not necessary to fill both arms full; merely have the liquid column a little longer in the long arm of the siphon, and as fast as the air is forced out of the tube end, the solution will take its place. After the siphon is filled ready to be set into the supports, the liquid can be retained in the siphon by simply placing a finger over the short end; air pressure will hold the solution in the long end. The students will be able, unassisted, to infer that the stalactite and stalagmite were formed from material in solution when the solution evaporated.

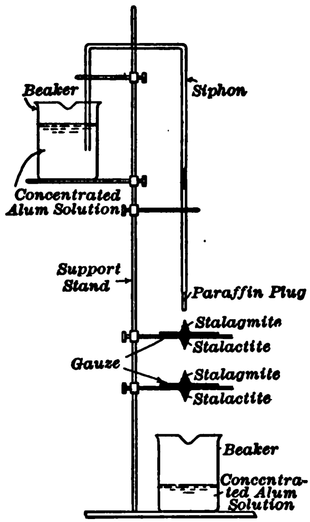


FIG. 69 (S).

Answers. — These questions will serve as interesting topics to be looked up outside of class and reported upon in class. Any good encyclopedia will furnish a wealth of interesting information on the subject.

1. (1) Evaporation of the solvent, carbonic acid (that is, water in which carbon dioxide gas has dissolved, and which dissolves calcium carbonate formations such as limestone, marble, etc.), which, as the solution drips from the cave roof, causes the solution to become supersaturated. There is consequently a deposit of the solute (calcium carbonate) from the solution. (2) As the solution drips from the cave roof, part of the carbon dioxide which is held in solution in the water because of the pressure is released when this pressure is somewhat lessened, for the same reason that carbon dioxide escapes from bottled soda water when the stopper is removed.

2. "(1) A very slow trickle of water from a fissure; (2) regular evaporation; (3) absence of disturbance, such as currents

of air. If the discharge of water is fast, irregular incrustations may be produced, or the precipitate of solid matter may be entirely washed away by the mechanical force of the currents. Changes of temperature will interfere with evaporation, sometimes accelerating and sometimes retarding it, and the stalactites tend under such circumstances to stop growth or to develop irregularities and excrescences."[1]

3. " . . . water percolating through the joints of the masonry has dissolved very small quantities of the lime present in the cement and mortar between the stones."[1]

4. Limonite, opal, chalcedony, fluorspar, gibbsite (seldom any of the preceding are over two or three inches long), ice, and sometimes in the interior of lava caves in the Sandwich Isles, basalt.

5. There is no sunlight, nor are there strong air currents, and the temperature is constant.

6. " Large stalactites may be 3 or 4 ft. thick, but in that case they have usually formed by the coalescence of adjacent ones which enlarged till they met and were then covered with a continuous layer of deposit. Single stalactites 2 ft. in diameter are not rare."[1]

7. " . . . two hundred thousand years may have elapsed since certain thick stalactites began to grow . . . but these estimates are probably ill-founded, seeing that there is no certainty that the conditions have remained the same during the whole period of growth."[1]

8. " If the stalactite and the stalagmite grow together forming a continuous deposit from the roof to the floor, it is called a column or pillar. A growth along the wall of the cave extending from the floor to the roof is called a pilaster."[2]

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[1] *Encyclopædia Britannica*

[2] Hopkins, *Elements of Physical Geography*

No. 85. HARD WATER

Materials. — Three test tubes; rain water; sample of water taken from the school well or faucet; a very little plaster, such as is used on the walls of houses, or a little plaster of Paris powder; borax; a little pure white soap.

Method. — The day before you are going to perform this experiment make solutions of the powdered plaster, which contains lime carbonate, or solutions of the plaster of Paris (calcium sulphate), and of the borax. Stir the powder in the water until you have a good solution, then set the solutions away to settle. Also make some strong soap solution. In the presence of the class, pour into the three test tubes respectively a little rain water, the plaster of Paris water, which is very hard, and the sample from the well or faucet, indicating to the class which is which. Pour into each test tube a little of the strong soap solution, and shake the contents of the tubes vigorously. The rain water will produce creamy suds; upon the surface of the tube of hard water will be a scum and no suds; and upon the surface of the other sample will be suds or scum, depending upon whether the water is hard or soft. The students will be able to infer that the scum or suds indicates hardness or softness in water.

If the local water is hard, a demonstration of how to soften it will prove an interesting addition to the experiment. However, as results are likely to be unsatisfactory, it is advisable not to attempt the demonstration before the class, unless you find, by trying it in private, that you will be successful.

Add some of the borax solution to a sample of the local water and set the mixture away for a few minutes to settle, then pour off the clear water and add soap solution to it. If successful, you will now be able to get suds, the water having been softened by the borax.

Answers. — 1. Well water is apt to have dissolved minerals in it which may produce hardness, while rain water is soft and, if it has been raining long enough to remove most of the dust and similar impurities from the air, is nearly pure.

2. In large cities, in which the water supply is hard, the proper amounts of chemicals (calcium hydroxide and sodium carbonate) necessary to soften the water are added in large tanks and thoroughly mixed, the clear water then being admitted to the mains, after the solid matter has settled out.

3. The acid carbonates, the chlorides and sulphates of magnesium and calcium, along with small quantities of other salts.

4. It is wasteful of soap, and the scum deposit is harmful to the fabric.

5. Borax and normal sodium phosphate in addition to the chemicals mentioned in Answer 2, above. Washing powders advertised to remove hardness in water frequently contain considerable proportions of borax.

No. 86. ROCKS

This is a companion experiment to No. 83.

Materials. — Samples from a mineral collection of granite, limestone, shale, marble, sandstone, basalt, or any others you may desire to study; knitting needle.

Method. — This experiment should parallel similar work in the text, which may be consulted frequently during the experiment in order to secure additional information not easily acquired by the student, or to check up the accuracy of his work. It may be well to give part or all of the following outline as a preliminary basis for the study:

Rocks Classes I. Sedimentary	1. Siliceous — mostly sand and gravel deposits cemented by clay, iron oxide, calcite, or silica. 2. Argillaceous — clayey rocks, as clays and shales. 3. Calcareous — limestone and marble rocks. 4. Carbonaceous—composed of carbon { coal. asphalt. 5. Ferruginous — containing iron ore. 6. Saline — containing rock salt. 7. Alkaline — containing soda and borax.

II. Igneous	1. Crystalline, granitoid, or plutonic. *a.* Granite. *b.* Syenite, etc. 2. Volcanic, glassy, or stony. *a.* Obsidian. *b.* Pumice. *c.* Basalt. 3. Intrusive or porphyritic, as porphyry.
III. Metamorphic	1. Sedimentary. *a.* Anthracite coal. *b.* Slate. *c.* Marble. 2. Igneous, as gneiss, serpentine.

The relative hardness of different samples may be ascertained with a knitting needle, as in No. 83. Structure may be roughly classified as crystalline or amorphous, stratified or uniform, compact or porous. Texture may be decided by the sample's being granular, earthy, compact, porphyritic (imbedded crystals), vitreous, or glassy. There are other subdivisions of each of the above classifications, but they need not be taken up in an elementary class. It may be found desirable to omit the composition. The color, of course, will depend upon the sample studied. As regards the table of qualities given on page 121, samples vary so much that it is impossible to give a condensed table which will be infallible, and while every effort has been made to give a dependable guide to the rock study, it may be well to check up your samples carefully with the table, before accepting the table as it is.

Answers. — 1. "A rock may be defined as a mass of mineral matter, composed of one, more usually of several, kinds of minerals, having as a rule no definite external form, and liable to differ considerably in chemical composition."[1] "A mineral may be defined as a single element, or two or more elements chemically combined, forming a part of the earth's crust."[2] An ore is a mineral which contains metals, not as a mixture with other substances, but in combination, generally with sulphur or oxygen, or carbon and oxygen; and usually in sufficient quantities to pay for the mining.

2. Heat, pressure, and chemical action.

[1] *Encyclopædia Britannica.* [2] Tarr, *New Physical Geography.*

ROCKS

Name	Class	Sub-class	Composition	Color	Hardness	Structure	Texture	Durability	Uses
Granite	Igneous	Granitoid	Quartz and feldspar always, and usually with any or all the following: mica, hornblende, serpentine and augite	Light, dark gray, or flesh-red	Very hard	Uniform Compact Crystalline	Granular	Very durable	Building stone, monuments
Limestone	Sedimentary	Calcareous	Calcite	Black, yellow, gray, reddish, white	Soft	Depends upon sample	Stratified, sometimes granular	Varies with sample	Fertilizer, in manufacture of chemicals and of steel, road metal, building stone
Shale	Sedimentary	Argillaceous	Clay, earth, or fine mud	Dull gray to red and black	Soft	Stratified Compact Amorphous	Compact	Not durable	Ceramics, bricks, etc.
Marble	Metamorphic	Sedimentary Calcareous	Calcium carbonate or limestone	White, or colored with streaks	Hard	Crystalline Compact	Compact	Durable	Statuary, monuments, building stone, etc.
Sandstone	Sedimentary	Siliceous	Sand cemented with clay, iron oxide, calcite, or silica	Red, gray, brown, white	Depends upon sample	Amorphous Compact or porous Stratified	Granular	Durable	Building stone, grindstones, etc.
Basalt	Igneous	Volcanic	Feldspar, pyroxene, and often magnetite and chrysolite	Black shading into gray, green, and brown	Hard	Amorphous Uniform and Compact	Compact	Durable	Road metal, building stone, etc.
Obsidian	Igneous	Volcanic	Silica and alkalies	Usually dull or translucent black	Very hard	Compact and Uniform	Vitreous	Durable	Gems, primitive implements, weapons

No. 87. MATERIALS WHICH MAKE UP SOIL

Materials. — Sample of soil; hand magnifying glass; glass plate.

Method. — Before class, place some of the soil to be examined upon the glass plate and examine it with the hand lens, in order to be familiar with the various constituents. Look for bits of gravel, grains of sand, clay, and small bits of decaying vegetable matter, such as leaves, roots, bark, etc. You will then be ready, when the class assembles, to show these different soil constituents, without unnecessary loss of time in hunting them. Call attention to the color, shape, and size of the different kinds of particles. There may be more than one kind of gravel, clay, and sand; but in an elementary course such as this, it may not prove worth while to attempt to classify these different bits, unless special study has already been made. The Method should contain a brief description, as indicated above, of the different kinds of soil materials found, along with their names.

No. 88. POROSITY OF SOIL

Materials. — A sample each of sand, fine gravel, clay, and ordinary soil or loam; four beakers or tumblers; water; pan or other vessel; test tubes of the same size with holes in the bottom, or lamp chimneys, or glass cylinders; empty chalk box, or test tube rack. If test tubes are used, plug the holes in the bottoms with a little absorbent cotton; if lamp chimneys or cylinders are used, tie thin cloth over one end.

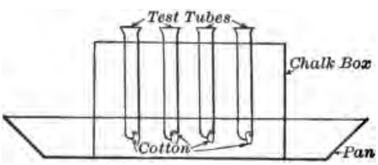

FIG. 70 (S).

Method. — If you have no test tube rack, a very satisfactory stand may be made by boring in the bottom of the chalk box four holes large enough to hold the test tubes without allowing their necks to pass through. (See Fig. 70.) Fill the test tubes

to the same depth, each with one of the different kinds of soil indicated above. If lamp chimneys are used, they may be filled and erected in the pan, with or without a ring stand to support them, depending upon how top-heavy they are. Set the chalk box in the pan, and pour into each of the test tubes in turn the same amount of water, using a different tumbler for each. Pour in only a little water at a time, and as soon as that has sunk in, pour in more until water begins to drip into the pan from the bottom of the tubes. Be sure to take the water for each tube from the same tumbler, each time. It will be very evident that water passes through the samples in this order: gravel, sand, loam, clay. It is probable that water will be dripping freely from the gravel and sand before much of the loam and clay has become moist, the water remaining standing upon the surface of the latter two for a few minutes before sinking in.

No. 89. CAPILLARITY OF SOIL

Materials. — Same as in No. 88, except that the test tubes are *filled* with the samples, and like the chimneys have thin cloth tied over their necks and are then inverted. (See Fig. 71.)

Method. — Invert the test tubes or the chimneys full of different soils in the pan containing water. The water will immediately begin to rise by capillarity more quickly in the gravel and sand, but it will rise highest in clay, next in loam, then in sand, and least in gravel. Explain that the ground is always full of little tubes, through which the water rises by capillary action, and that the smaller these tubes, the higher the water will rise; that the tubes in clay are much smaller in diameter than those in gravel, and hence the water rises higher in the clay. It will take several days to perform this experiment, and the water will have to be renewed frequently.

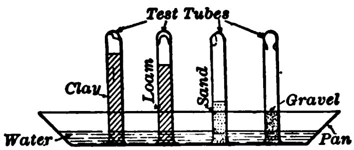

FIG. 71 (S).

No. 90. CAKING OF SOIL

Materials. — Six pans, two filled with sand, two with clay, and two with loam; water; stick.

Method. — Thoroughly wet the soils in all the pans. Stir one pan each of clay, loam, and sand several times in the course of the next day or so, as they dry. The loam will probably cake to some extent, and the clay will be sure to cake. Allow the clay, loam, and sand in the other three pans to dry undisturbed. The clay will crack, to some extent, as will also, possibly, the loam. It will be evident that the caking has been increased by working the soil while it was wet.

No. 91. AIR CONTENT OF SOIL

Materials. — Bottle half filled with soil which has been taken from a point several inches below the surface; water; rubber stopper or cork which exactly fits the bottle.

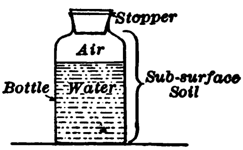

FIG. 72 (S).

Method. — Pound the soil down hard in the bottle, so that all obvious holes and spaces are eliminated. Fill the bottle entirely full of water, and put in the stopper. As the water sinks into the soil, it will displace air, which will rise under the cork. After a day or so, the top of the bottle under the cork will be full of air to a depth of several inches.

No. 92. FERTILIZATION OF SOIL

Materials. — Two chalk boxes; sand; some poor soil, such as clayey soil; some well-rotted manure; radish seeds.

Method. — Fill the boxes, one with the clay, and the other with a mixture of clayey soil, sand, and manure. Soak the radish seeds over night, and then sow the same number of seeds in each box, covering them lightly with soil. Place the boxes in the window or other warm place where the seeds will

have an equal chance for growing. Water the plants from time to time, but give them no other care, except to pull up any weeds which may grow in the boxes. The class will observe the growth of the plants for a week or more, during which time the benefits of fertilizing will be plainly evident.

No. 93. IMPORTANCE OF SOIL MULCH

Materials. — Three chalk boxes nearly full of wet soil; water; sawdust; dry soil.

Method. — Put over the top of the second box, a layer of finely pulverized dry soil, 1 in. thick, and over the top of the third, a similar layer of dry sawdust. Place all three boxes in the window, or where they will have the same conditions of temperature. When the soil in the uncovered box seems dry, remove the protective layers from the others. The soil in the boxes which have had loose layers over them will be found to be still damp. The students will therefore be able, unassisted, to infer that moisture may be conserved in the soil either by cultivation, or by putting a "mulch" of loose material upon the top of the ground.

Answers. — **1.** See Answer 14, No. 104 (page 146).

2. "The amount of capillary water which a soil can hold depends on the extent of surface of the soil particles. We have learned that surfaces increase as the squares of their like dimensions, while solids increase as the cubes of their like dimensions. A grain of sand has a greater surface in proportion to its size than a pebble has. Therefore a cubic foot of sand will hold more *capillary* water than a cubic foot of pebbles." [1]

3. The capillary water, which forms a film around the soil particles, is absorbed by the root hairs of the plant.

4. ". . . cultivation of the soil increases the size of the pores, and consequently checks the rise of water through the cultivated layer, thus diminishing the loss by evaporation at the surface." [2]

[1] Grim, *Elementary Agriculture.*
[2] Coleman, *Text-book of Physics.*

5. " . . . The surface soil is . . . most thoroughly cultivated, so as to make as perfect a soil mulch as possible. Thus, whatever moisture falls is kept from seeping below the reach of the plant roots and from evaporating from the surface. In this kind of farming, the aim is to use more than one year's moisture in growing a crop." [1]

6. " (1) It makes the soil lighter and more porous, thus improving its condition. (2) It helps the soil to hold heat and moisture. (3) It supplies food for growing plants. (4) It promotes the growth of useful bacteria." [2]

7. " In their [worms'] bodies, digestive fluids are added to the soil that has been eaten, and when voided from their bodies, the soil is changed so that its fertility is increased. Also, the burrows of the earthworm provide added opportunity for air to enter the soil — a matter of much importance." [3]

8. A fertile soil contains in combination the principal elements needed by the plant: oxygen, hydrogen, nitrogen, iron, phosphorus, and potassium. It also contains no substances injurious to plants, has favorable water content, and favorable texture and physical composition.

9. Humus is partly decayed animal and vegetable matter obtained in the soil by the decay of roots, stubbles, and manures plowed under. (See Answer 6 above.) Humous soil is dark, the darker the color, the more humus the soil contains.

10. Hard, compact, clayey soils.

11. " Plants and animals and human bodies are made up of substances which occur in a simple state in nearly every handful of earth. Man cannot use these simple substances *directly* as food, but plants can and do; and man and all the higher animals live on plants, or on other animals which thrive on plants." [2]

12. " Every agriculturist needs to know what his soil contains, what it lacks, for what crops it is suited, and how it ought to be handled, so that it will give as great

[1] Snyder, *First Year Science.*
[2] Grim, *Elementary Agriculture.*
[3] Caldwell and Eikenberry, *Elements of General Science.*

a present yield as possible, without losing its fertility for the future." [1]

13. "If the crop is changed at intervals, the field that has lost a great deal of an element has time to recover, and to get enough of that element into a form in which the plant can use it. The root systems of plants are different; hence one plant often breaks up the ground for another. A long growing of the same plant in a field frequently allows plant diseases or harmful insects to get a strong foothold. When the crop is changed, the new plant is usually immune; that is, not affected by the disease." [1]

14. "If a soil becomes acid, or 'sour,' it needs a basic substance to make it 'sweet.' Lime and limestone are used for this purpose. These substances also have important effects on the *structure* of the soil. A very sandy soil is not fertile, because its particles are too far apart, and do not retain water. Lime and limestone help to cement the separate grains together, forming a less porous soil. While they make a sandy soil *less* porous, lime and limestone make a clayey soil *more* porous; they separate the particles of clay, which cohere too closely, by forming a 'nucleus,' or center, to which the clay particles can adhere. The soil particles are thus made larger, and the soil is made more porous." [1] (See also Answer 9, No. 79.)

15. When water freezes it expands. The freezing of the soil water, therefore, has a tendency to render a heavy soil more porous, by breaking it up.

16. Wood ashes contain an alkali or base which neutralizes the acid in the sour soil. After a year or two, however, the roots of the plants give off enough more acid to make the soil again acid.

17. "(1) The nitrifying bacteria, (2) the nitrogen-fixing bacteria, and (3) the nodule bacteria." . . . Nitrifying bacteria "transform the nitrogen-bearing compounds of the soil humus into a form available for the higher plants" but "do not actually add any nitrogen to the soil." [2] The nitrogen-fixing bacteria

[1] Hessler, *The First Year of Science.*

[2] Barber, *First Course in General Science.*

"take the free atmospheric nitrogen and fix it in compounds which ultimately become available for the higher plants. . . . Unlike the first group, . . . these bacteria are thus able to add to the total nitrogen content of the soil."[1] Nodule bacteria, "like the second group, have the power of fixing atmospheric nitrogen but they seem to be able to do this only when they live within the root tissue of certain higher plants, mainly those that belong to the botanical family which includes clover, alfalfa, beans, peas, and the like."[1]

18. Glacial soil will be found in all parts of the United States which were formerly covered by the Great Ice Sheet: "New England, northern New Jersey, nearly all of New York, northern Pennsylvania, much of Ohio, and the states farther west and northwest, as far as Montana . . ."[2]

19. "Throughout the glacial belt the drift soil shows many variations; for example, stony, clayey, sandy, gravelly, level, irregular. On a single farm there may be several kinds of soil. Sometimes this is better than the soil of rock decay that existed before the ice sheet came; in other cases a barren, sandy, gravelly, or bowldery soil has been left in place of a fertile, residual soil. Usually the glacial soil is a strong one, because it consists of ground-up rock fragments, which are slowly decaying and releasing plant food."[2]

No. 94. TO MAKE A TOPOGRAPHICAL MAP

Materials. — Large parsnip or carrot that tapers rapidly, (if it does not, point it with a knife so that it does), cut off crosswise where it is biggest around, so that it tapers all the way to the point, and will stand vertical upon a flat base (see Fig. 73); ruler; pin; sharp-pointed pencil; two big hatpins; knife.

Method. — Set the carrot upon a sheet of notebook paper, placed upon a board (not the table), and set up the ruler

[1] Barber, *First Course in General Science.*
[2] Tarr, *New Physical Geography.*

vertically beside it. Hold the pin upon the ½-inch mark so that the point projects about ¼ inch beyond the edge of the ruler. (See Fig. 74.) Turn the carrot around in a circle, keeping the pin point against it, so that a line is scratched into the carrot, every point of which is ½ inch from the base level (top of the board). Tell the class that the top of the board represents sea level, which is the level used as a basis for all topographic

FIG. 73 (T).

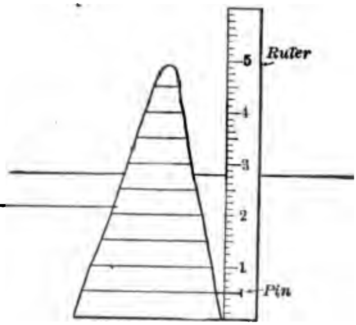

FIG. 74 (T).

maps, and that the carrot represents an island. Point out the fact that every point on the line, which you have just scratched around the carrot, is the same *vertical* distance from sea level, and that this line represents a *contour line*. Scratch similar lines around the carrot in the same way, each being ½ inch above the last. When you have come to the top of the carrot, lift the carrot, and thrust the hatpins through it from top to bottom, keeping both hat pins inside the topmost circle but at the same time keeping them as far apart as possible. (See Fig. 75.) Make big holes clear through the carrot, then place a sheet of notebook paper upon the board, and place the carrot upon it in the same position as at first, thrusting both hatpins firmly through the paper into the board. (See Fig. 75.)

Now, with the pencil, follow around the base of the carrot,

telling the class that this line represents the outline of the island where it first rises out of the ocean. With the knife cut off the slice of carrot at the first ring made by the pin, and remove the slice. Again thrust the hatpins through *exactly the same holes* in the carrot as before, through the paper and into the board once more. The pins will not pass through the same holes in the paper as before, because the lowest slice of carrot has been removed, but they will be exactly in a line drawn between the original holes in the paper, and will be a

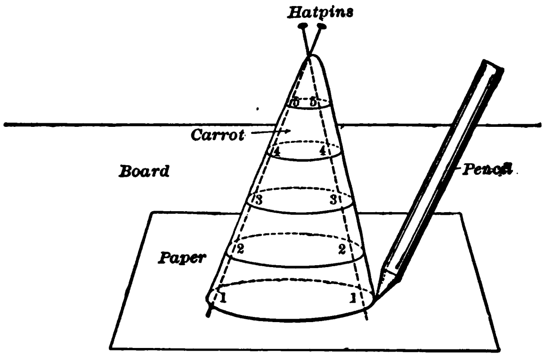

FIG. 75 (T).

little inside of the original holes, *i.e.*, they will be a little closer together than the original holes. (See Figs. 75 and 76.)

Again trace the outline of the bottom of the carrot upon the paper. This outline will be a smaller circle inside the first one. Cut off the next slice, and, keeping the hatpins always through exactly the same holes in the carrot and in the straight line between the original holes and just inside, *i.e.*, a little nearer together than the last pair of holes for the preceding slice, draw the outline of each new base, until the top of the carrot is reached. (See Fig. 76.) One should take care to keep the hatpins always in the straight line drawn between the holes made in the first and largest slice, so as to keep the carrot always in the same relative position on the paper, and to insure the contour lines

being in the correct relation to each other. Explain that each line drawn around the carrot is a contour line, and that in this case the *contour interval* is ½ inch.

The students will probably need some assistance with the Conclusions before they will see that a contour line connects all points at the same vertical height above sea level, and that the contour interval is the vertical distance between contour lines.

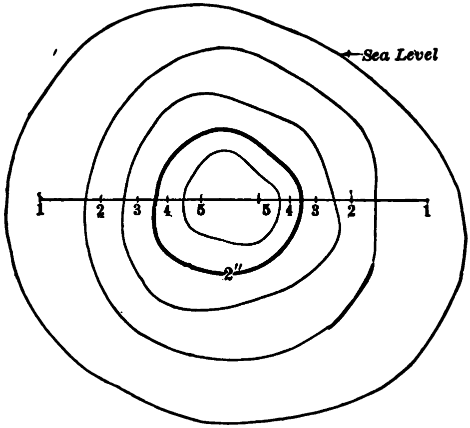

FIG. 76 (S). Scale ¼. Contour Interval ½".

Instruct the class to make the fourth line heavy and to write **2** in a break in this line. (See Fig. 76.) This will help them to understand later the meaning of the heavy lines on a regular government contour map.

No. 95.
PRELIMINARY STUDY OF A TOPOGRAPHICAL MAP

This preliminary study of a topographical map has proved to be a valuable exercise, since it makes the student familiar with the topographic map and how to interpret it.

Materials. — Almost any of the government topographical maps which may be obtained from The Director, United States Geological Survey, Washington, D. C., at a few cents each. Choose, preferably, a sheet representing country partly flat and partly hilly, with rivers and streams, and, if possible, forest areas shown. The sheet for Mt. Hood, Oregon, is excellent. It is better to allow each student or small group of students

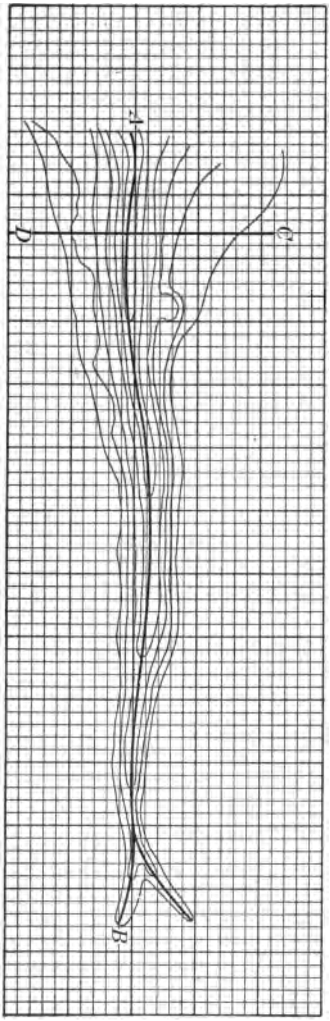

FIG. 77 (S).

to study a sheet, than to try to demonstrate the whole experiment yourself, though the latter method will give good results.

Answers. — **1.** The lay of the land (all elevations and depressions), all natural and man-made features.

2. Given at the bottom of the sheet. A contour line connects all points the same height above sea level; the contour interval is the vertical height between adjacent contour lines. If the scale is $\frac{1}{62500}$, the map is therefore $\frac{1}{62500}$ of the actual area of the portion of country represented on the map; *i.e.*, the scale means that for every inch on the map there are, in reality, 62,500 inches; or the scale is very nearly an inch to a mile. If it were exactly an inch to a mile, the scale would be $\frac{1}{63360}$.

3. Uneven or hilly.

4. Fairly level. It may represent a plain or a plateau.

5. To facilitate the reading of elevations, the contour lines representing even hundreds of feet (usually) are heavier than the other contour lines.

6. Roads are more likely to follow than to cross contour lines, in order to avoid steep pitches.

7. The road ascends toward the sharp bend.

8. Upstream.

9. Downstream.

10. More contour lines cross mountain streams than valley streams, because of the more rapidly rising land in the mountains.

11. Blue represents water, as lakes, rivers, etc.; green, forest areas; white (absence of brown contour lines), level country;

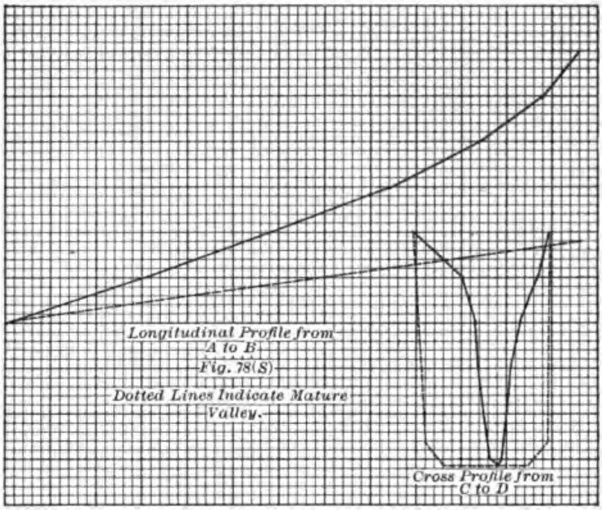

FIG. 78 (S). FIG. 79 (S).

brown (caused by proximity of contour lines), hilly or uneven country.

12. Contour lines on hills form approximate circles; on a ridge the contour lines run more nearly parallel to each other.

13. By black, rectangular dots.

14. Black.

15. (1) Automobilists may use contour maps for road maps, to determine steepness or directness of roads, camping sites, etc.; (2) Summer campers may select a site for a camp almost as well from a contour map as from seeing the country; (3) To

determine reservoir sites; (4) To determine trolley routes, since the nature of the country, patronage (as indicated by the number of houses), territory, etc., between towns, is indicated. For Diagram 1, see Figs. 77, 78, and 79; for Diagram 2, see Figs. 80 and 81.

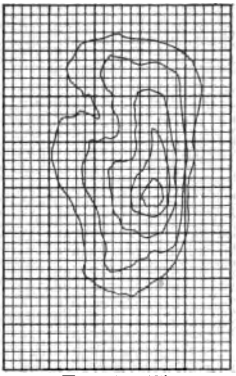

FIG. 80 (S).

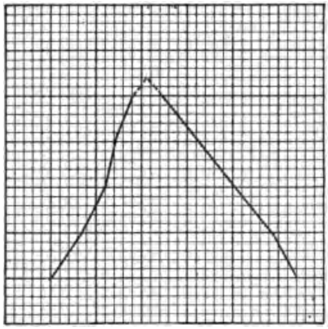

FIG. 81 (S).

SPECIAL STUDY OF TYPICAL TOPOGRAPHICAL MAPS

In the five following exercises on contour maps, the questions have been carefully selected with a view of making each one contribute a suggestion which will be productive of thought and interest on the student's part. The questions are also intended to correlate with whatever text is used, and to clear up various ideas and topics developed in the text and make them concrete. Therefore, encourage text reference work. There is a distinct advantage in allowing the student to draw the profiles first, before working out the answers to the questions, as it gives him a better idea of the lay of the land he is studying.

No. 96. STUDY OF CRATER LAKE

While this and the following experiments may be used entirely as a demonstration by the teacher from a single map,

it will give more satisfactory results if each student, or group of two or three students, can have a sheet to study.

Method. — Since every late edition of the sheet for Crater Lake contains so much valuable information on the back, it would prove a waste of time to ask questions, the answers to which the student could better learn by simply reading what is printed there. The questions, therefore, are merely such as will help to afford a better correlation between the sheet itself and the information on the back and whatever text you may be using.

Answers. — **1.** The depression contours on the top of Wizard Island indicate the presence of a former crater.

2. For a considerable distance in all directions from Wizard Island, the lake is less deep than it is further west, and from a point about a third of the distance across, the lake deepens abruptly.

3. About a mile south of Pumice Point are three soundings of less than a thousand feet, and all about, the soundings are above twelve hundred feet.

4. Glacier Peak is 6 ft. higher than Dutton Cliff; Scott Peak, about $2\frac{1}{2}$ mi. from the lake, is 782 ft. higher than Glacier Peak.

5. A rock.

6. "Not all the lava that starts toward the surface reaches it. For example, when eruptions cease, the vent of a volcano becomes filled with solid lava. . . . The long, narrow sheets filling the fissures, through which lava escapes on the flanks of a volcano, are called *dikes*. In the neighborhood of volcanoes, similar dikes are intruded into the rocks . . . deep in the earth. These and other forms of intruded rocks are brought to light by denudation." [1]

7. The contour lines show that there is no level land along the margin.

8. The lava was drained away below, causing the top of Mt. Mazama to cave in, thus leaving an abrupt slope from the rim of the caldera. Wizard Island was formed by subsequent eruptions which spread out around its base.

9. Calderas are sometimes caused by an explosion which blows away the top of the volcano, leaving usually a jagged,

[1] Tarr, *New Physical Geography*.

uneven rim; they are also formed, as in the case of Crater Lake caldera, by the draining away underneath of the lava.

10. It is the deepest fresh water lake in America and perhaps the most beautiful lake of its kind in the world; though there are other crater lakes in America, Crater Lake occupies the only true caldera on this continent.

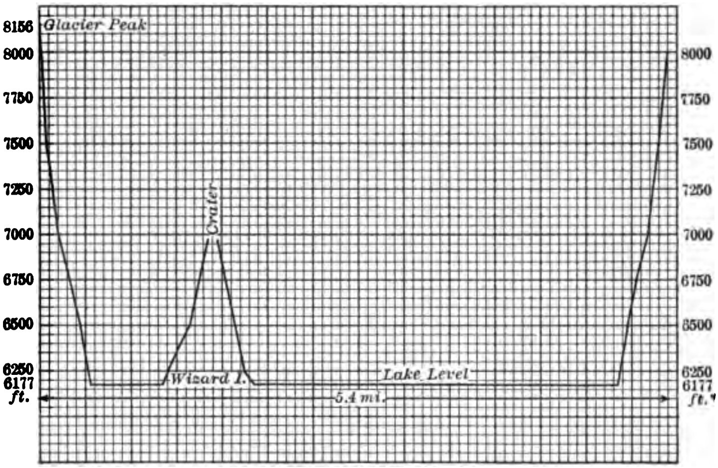

FIG. 82 (S).

No. 97. STUDY OF MOUNT SHASTA

Here, as suggested above, in the paragraph preceding the Crater Lake study, it will be found an excellent plan to require the student to make the profile before he works out the answers to the questions, as in that way he will get a much better idea of the lay of the land.

Answers. — 1. Northern California. Shasta is in the southern end of the Cascade Range.

2. The large well-developed glaciers; the fact that no crater

remains; the deep mountain valleys; the somewhat rounded top of Shasta and of the neighboring cinder cones.

3. It is most probable that Shasta is extinct; but the fact that there is volcanic activity within a comparatively few miles of it, and in a continuation of the same great range, coupled with the fact that long periods of inactivity may be followed

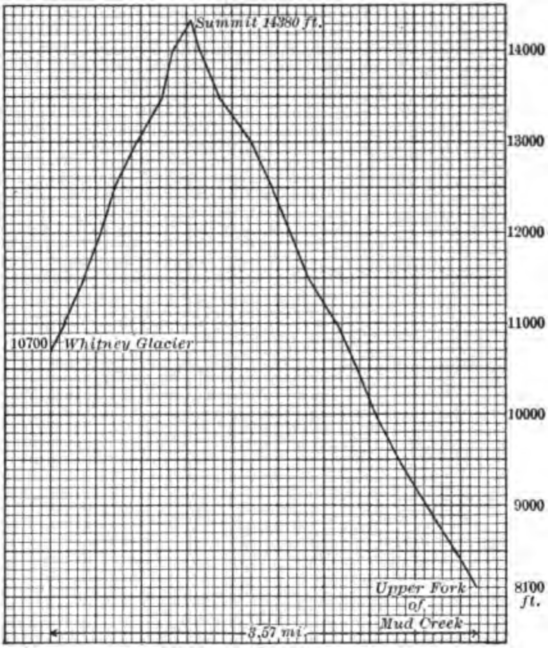

FIG. 83 (S).

by violent eruptions, indicates that Shasta may be merely dormant.

4. Shastina is a cinder cone which developed later than Shasta.

5. The cinder cones near Shasta were formed in the same way as Shastina, the volcanic activity dying out before these attained any considerable size.

6. Deeply weathered sides; well-developed valley glaciers; the fact that the crater has been worn away; the steep cliffs upon its sides.

7. Shastina is younger because it shows to a much less degree the effects of weathering. It also retains most of its crater, though this fact is not obvious from the sheet.

8. The broadness of the base of Shasta and the departure from the true cone shape, are indications that there were fissure eruptions through the sides of Shasta. The course of this lava flow is easily traceable from the base of the mountain.

9. The small cones were doubtless cinder eruptions, probably much more violent than the fissure eruptions mentioned in the last question above. The top of Shasta was also doubtless built up, for the most part, by a cinder eruption.

10. The lava ash is porous, and the water sinks into the pores of the rock.

11. Mud Creek is older, as is evidenced by its broader valley. It has cut into the ash, while Squaw Creek is still cutting through the harder, superimposed lava.

12. The streams are fed by the glaciers, most of which are on the northeastern side.

13. The weathering and erosion have been great, since the cliffs are steep and narrow.

No. 98. STUDY OF A GLACIAL REGION

Materials. — Sheet for Boothbay, Maine.

Answers. — **1.** Southern.

2. From north to south.

3. Low, flat-topped hills, and numerous ponds.

4. Cordilleran, in Western Canada; Keewatin, just west of Hudson Bay; Labrador, east of Hudson Bay.

5. From the Labrador center.

6. Sinking.

7. About 30 ft.

8. Four. The industries must have to do with the sea, and are chiefly fishing, commerce, and shipbuilding.

9. The fact that most of the villages are on the shore indicates also the nautical nature of the industries.

10. By water and by wagon road.

11. England and Norway.

No. 99. STUDY OF OFFSHORE BARS

If time permits, it will be found interesting and worth while to make a comparative study of the sheet for Boothbay, preceding or following this experiment.

Materials. — Atlantic City Sheet.

Answers. — **1.** Southeastern coast.

2. Whenever an offshore current from a river or an undertow, carrying great quantities of sediment, is checked by incoming waves or ocean currents along the shore, the bottom at that place being shallow, the sediment is dropped, forming offshore bars or barriers.

3. The northern ends of the offshore bars shown on the map are hooked toward shore, because the outflowing river current is checked by the sweep of part of the Gulf Stream along the coast, the sediment being deposited at the points where two currents are slackened by meeting at right angles.

4. It is formed under the lee of the hook upon which Atlantic City is built, being therefore protected from the current from the south.

5. Mullica and Wading rivers empty into Great Bay, and the current from these and the little river emptying into the salt marsh at Absecon, keep the sediment which now forms hooks on the beaches, from stretching straight across.

6. An abundance of sediment was furnished when the waves formerly beat upon shore, forming a shore cliff (the low one indicated upon the border of the mainland). Short bars were then formed at the edges of the little bays, and finally the amount of sediment was sufficient to form the offshore bars, as explained

in Answer 2 above. The lagoon behind these bars became a salt marsh, and is being filled by sediment from the rivers and by dust blown from shore by the winds.

7. "In a further stage, the offshore bar would be pushed back and the waves once more allowed to attack the mainland."[1]

8. None. There would be a few small islands just south of Atlantic City.

9. Only three small islands on Absecon Beach. Atlantic City is built upon Absecon Beach because this beach is both the broadest and the highest of the offshore bars.

10. Six life-saving stations and one lighthouse. Absecon Light is in a sufficiently prominent position to be visible for a long distance up and down the coast; the life-saving stations are necessary both because of shipping, and because of the fact that these beaches are famous bathing resorts.

11. Four; principally to bring the people to the beach resort.

12. The few fertile tracts on the mainland are farmed; fishing is done along the coast, but the industries center chiefly around the seaside resort.

No. 100.

STUDY OF A PORTION OF AN OLD RIVER

It is best to allow the student to make his profile first, as he will thus get a better idea of the lay of the land.

Materials. — Donaldsonville, Louisiana, Sheet.

Answers. — **1.** Flat.

2. Along the river margin, because natural levees have been built there by the river, and later, artificial ones have in many places been superimposed by man, both of which tend to raise the banks above the surrounding country.

3. Less than 5 ft.

4. A river cuts on the outside of a curve and deposits upon

[1] Tarr, *New Physical Geography*.

the inside, where the current is less swift. The sediment was washed down to the swamp margin (see "Alluvial Deposit from Nita Crevasse").

5. During high water, when the river is carrying its heaviest load, it overflows its banks; since the current away from the main channel is therefore slackened, the river is no longer able to hold its load, and consequently deposits it in the quiet water along the margin of the stream. The result of this process is to build up the banks.

6. Bayou des Acadiens, Blind River, Bayou Conway, Bayou Napoleon, Bayou Verrette. They flow away from the Mississippi because the land is highest on the banks of the Mississippi.

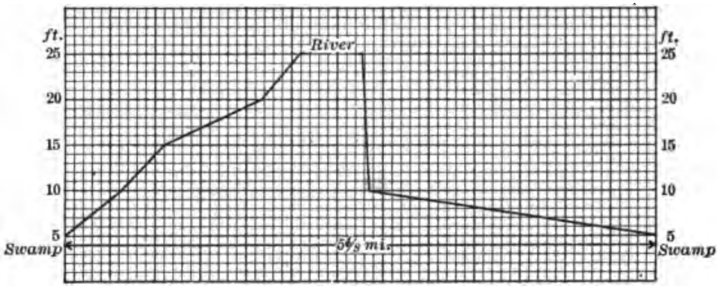

FIG. 84 (S).

7. Cotton, rice, and sugar are grown as principal crops in the strips between the river and the swamps. The ditches are dug to drain off the water into the swamps caused by the heavy rainfall of the region, otherwise the water would stand upon the level ground.

8. A little over 15 mi. Between 23 and 24 mi.

9. See Answer 9, No. 104.

10. Broad flood plain, meandering course, natural levees, flood plain swamps.

11. Oxbow lakes, oxbow cut-offs, rolling divides, deltas, etc.

12. To take the produce to the river and the railroads.

13. Malarial and yellow-fever mosquitoes find an ideal breeding place in swamps. Malaria and yellow fever can be-

come epidemic, however, only provided the particular mosquitoes which carry them are present, and only then when the female mosquitoes, during the time they are maturing their eggs, bite these patients, and subsequently inoculate other people by biting them in turn.

14. Louisiana was a French province until the Louisiana Purchase, 1803.

No. 101. STUDY OF AN IRRIGATED DISTRICT

It is best to allow the student to make his profile first, as it gives him a better idea of the lay of the land.

Materials. — Lamar, Colorado, Sheet.

Answers. — **1.** Southeastern part.

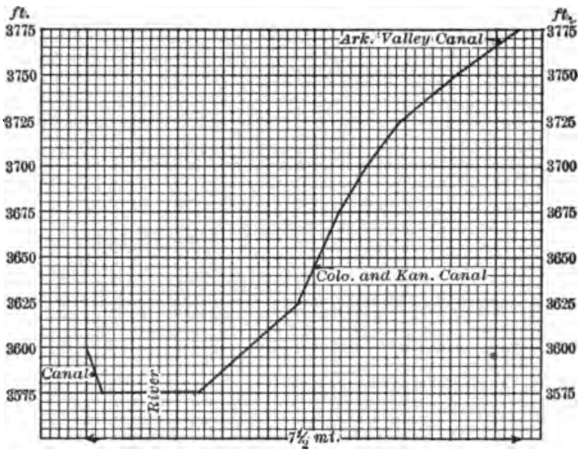

FIG. 85 (S).

2. Dry weather streams. That is, they flow only during the rains, or rainy season.

3. Most of the lakes also are dry during the greater part of the year.

4. Irrigation of the land between the canals and the Arkansas River.

5. The Arkansas Valley Canal is about 200 ft. higher than the Colorado and Arkansas Canal at the point indicated on the eastern edge of the sheet. The former canal irrigates the land between the two canals, while the lower one irrigates the land between it and the river. Refer the students to their profiles as an aid to understanding this question. (See Fig. 85.)

6. The canals must of necessity follow the contour lines very nearly. The southern canals are more direct than the northern ones, because they happen to be in more nearly level country.

7. In the river, because it has a much greater fall per mile.

8. The dry weather lakes occupy sink holes, due to the presence underground of caves formed by underground water in soluble rock such as limestone, rock salt, and gypsum. The roofs of these caves sometimes collapse, forming sink holes.

9. Farming. The class will be interested to know that the principal crops of this region are alfalfa, sugar beets, fruits, grains, and vegetables.

WEATHERING, EROSION, DENUDATION, AND DEPOSITION

The three following experiments are intended to correlate with text work on weathering, erosion, denudation, and deposition.

Weathering is the discoloration, rounding-off, and final breaking-up of rocks. *Erosion* is the gnawing away of rock formations. *Denudation* is the result of the combined effects of weathering and erosion. *Deposition* is the depositing of eroded stones and finer particles.

No. 102.
EXPANSION OF WATER THROUGH FREEZING (WEATHERING)

Materials. — Two small test tubes or thin glass bottles, with cork to fit one; cold water; chipped ice; coarse salt.

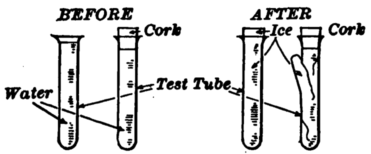

FIG. 86 (S).

Method. — Fill the test tubes or the bottles exactly full of water and tightly fit the cork into one. Place them in a freezing mixture of equal parts of chipped ice and coarse salt. If the weather is very cold, no freezing mixture is necessary, — the bottles may be merely exposed to the cold. Test tubes will probably prove more satisfactory than bottles, because they are apt to be thinner, and will allow the heat to escape sooner from the water contained in them, and hence will permit more rapid freezing. The *stoppered* tube will be broken by the expansion of the water (increase in volume) as it freezes, and the open one will have a plug of ice extending out of the top of it, perhaps half an inch or more. (See Fig. 86.)

No. 103.
EVIDENCE OF EROSION AND DENUDATION BY RIVERS

Materials. — Jar or bottle of river water taken during high water, when the river is muddy.

Method. — Shake the contents of the jar thoroughly, explaining to the class that it is river water. Then set it aside for a few days or a week. At the end of that time the sediment will have settled. The students will infer that a river cuts into its banks and bed and carries away the finer particles in suspension.

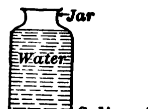

FIG. 87 (S).

No. 104.

STRATIFICATION BY WATER (DEPOSITION)

Materials. — Jar or bottle; soil composed of gravel, finer particles, sand, and clay; water.

Method. — Fill the jar half full of the mixed soil, and then fill it with water. Shake the jar thoroughly, and set it away for several days. The gravel will be found to have settled first, and the clay particles will be on top.

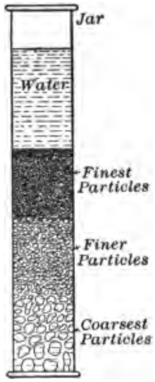

FIG. 88 (S).

Answers. — **1.** See definitions on page 143.

2. Ground-water percolates into cracks in the rock, freezes, and expands; the force of this expansion is sometimes sufficient to break off huge layers and pieces of rock.

3. (1) Air: (*a*) hot, expansion; (*b*) cold, contraction or freezing; (*c*) chemical action; oxidation, action of carbon dioxide; (*d*) wind carries dust and sand, and acts like a sand-blast.

(2) Plants. The roots of plants pry off fragments of rock and remove mineral substances. Decaying vegetation supplies organic acids which assist in weathering.

(3) Animals. Their chief value as agents of weathering is that they tunnel holes through the ground which allow air and water to enter.

(4) Percolating water as ground-water, solution of minerals.

4. Corrasion is weathering by mechanical means, as by extremes of heat, etc. Corrosion is weathering by chemical action, as by organic plant acids, solution by soil water, etc.

5. (1) "The formation of residual soil, or soil of rock decay; (2) the supply of soluble mineral substances to water; (3) the formation of talus and avalanches; (4) the supply of cutting tools to rivers; (5) the supply of materials for the formation of sedimentary strata; (6) valley broadening; and (7) rock sculpturing."[1]

[1] Tarr, *New Physical Geography.*

6. (1) Winds; (2) glaciers; (3) waves of oceans, and of lakes; (4) running water as streams; (5) ground-water.

7. The same list as for Answer 6.

8. The same list as for Answer 6.

9. "On entering a sea or lake, a river finds its current suddenly checked. Some of its sediment is removed by waves and currents, but much is deposited in the quiet water near its mouth, building up land. To this land the name delta is applied, because of its resemblance to the Greek letter delta (Δ). . . . deltas have the triangular shape because a single channel will not carry all the water over their level surface. For this reason the river divides into channels, or *distributaries;* which spread apart and enter the sea by separate mouths." [1]

10. The water is shallower, and there is usually an absence of tides and large waves.

11. "A stream flowing from a steep to a gentle slope has its velocity checked. If it has much sediment, some may be deposited where the slope changes. Such a deposit is called a *cone delta*, or *alluvial fan*." [1]

12. (1) "The soil is good; (2) there is a supply of water at the upper part of the fan; and (3) there is a good grade down which to lead the water." [1]

13. Near the margin or bank; farther out, the smallest often being many miles from the river mouth. The ability of a current to carry a load varies as the sixth power of its velocity. Thus if the speed of the current is doubled, the stream may carry particles sixty-four times as heavy.

14. The soil is renewed by every flood, the old soil being completely covered by a deposit, which contains all the elements needed by plants. The Nile is a striking example of a river which by its annual floods makes agriculture possible along its banks.

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[1] Tarr, *New Physical Geography.*

No. 105.

RELATION BETWEEN THE COTYLEDONS AND THE GROWTH OF THE SEEDLING

Materials. — Pasteboard box or can filled to a depth of about 1 in. with sawdust or bran; a few pea seeds; bottle, tumbler, or flask; square of cheesecloth; string.

Method. — Moisten thoroughly the sawdust in the box, and after soaking the peas for 12 hr. or so, plant them in the sawdust, covering them lightly with a layer of damp sawdust 1 in. deep. Sprinkle the sawdust every day or so, if it gets *dry*, and keep the box in a warm place; in the window where the sunlight can fall upon it, is good. In 3 or 4 days the seeds will have sprouted sufficiently so that they may be transferred to the bottle for the main experiment. Fill the bottle with water and tie the cheesecloth tightly over the top. Pierce the cheesecloth in two places and insert the roots of two of the sprouted peas. Be sure that the water touches the roots. After another day or so during which the seedlings will have grown perceptibly, carefully remove the cotyledons (the two halves of the pea seed) from the more vigorous plant. The less vigorous plant with its cotyledons retained will outstrip the one which has been deprived, inside of the next day, and will grow rapidly, while the one without the cotyledons will practically cease to grow. (See Fig. 89.)

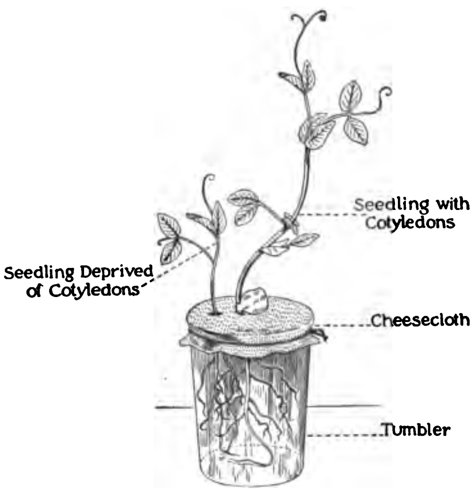

FIG. 89 (S).

Answers. — **1.** At the beginning of its growth, all the food of the plant is contained in the seed. Removing the cotyledons removes most of the reserve food of the seed.

2. Monocotyledon, a plant having one seed lobe or seminal leaf; dicotyledon, a plant having two seed lobes or seminal leaves. The pea and the bean are dicotyledonous plants; the corn is monocotyledonous.

3. The pea is a plant with underground cotyledons, because the cotyledons remain underground during the plant's development; the bean is an aboveground cotyledonous plant, for its cotyledons are thrust up above the surface of the ground. Only dicotyledonous plants are thus further classified.

4. The primary or taproot is the big root which is first sent down by the seedling; the secondary roots sprout out of the sides of this primary root, after a few days.

5. Proteins and carbohydrates (starch) mostly, but in some cases, also oils.

6. "In dicotyledonous seeds of the type of the pea, the horse-chestnut, and the buckeye, the cotyledons remain inclosed in the seed coat and underground, where they become emptied of their contents. . . . In the bean, they are raised into the air, turn green, develop stomata, and probably for a short time do some photosynthetic work, but soon wither and fall off. In the squash, pumpkin, and most dicotyledonous plants of the farm and garden, the cotyledons become for a considerable time active green leaves, but they are shorter-lived than the subsequent leaves of the plant." [1]

No. 106.

AIR — A NECESSITY OF GERMINATING SEEDS

Materials. — Soaked peas or beans; two similar bottles, one fitted with a tight stopper.

Method. — Soak the peas or beans overnight, then place ten in each bottle. Tightly stopper one bottle, but leave the

[1] Bergen and Caldwell, *Practical Botany*.

other open. Place both bottles side by side in the window, and observe them during a week or more. The seeds in the open bottle will continue to germinate but those in the stoppered bottle will soon cease to show any activity. The necessity for a constant supply of fresh air is obvious.

No. 107.
RESPIRATION OF GERMINATING SEEDS

This experiment should be preceded, somewhere in the course, by No. 77, on Carbon Dioxide.

Materials. — The stoppered bottle used above; glass stirring rod; clear limewater; empty bottle.

Method. — Dip the glass stirring rod into the limewater, and removing the stopper from the bottle, insert the stirring rod in the bottle. After a few moments remove it, and let the class examine it. The limewater will be whitened, showing that the bottle must contain carbon dioxide, which could have been evolved in such quantities, only by the seeds during the germinating process. Wipe off the stirring rod, again dip it into the limewater, and insert it in the empty bottle. After a few moments remove it, and show it to the class. The absence of any whitening, as previously noted, will serve to impress the fact that the CO_2 resulted from the germinating of the seeds.

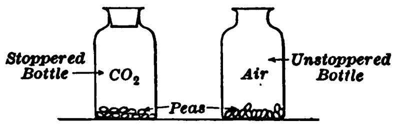

Fig. 90 (S).

Answers. — **1.** The carbon which was in the foodstuff in the seeds soon exhausted the scanty supply of oxygen which was in the stoppered bottle, by uniting with it to form carbon dioxide. No further energy could be released in the seed, therefore, until more oxygen was admitted.

2. Air, containing oxygen, is allowed to reach the seed. This air, aside from bringing about the release of the energy needed by the germinating seeds, acts upon some of the soil

materials, putting them into a form that the germinating seeds can utilize.

3 and **4.** See Answer 7, No. 93.

5. Respiration.

No. 108. IODINE STARCH TEST

Materials. — Test tube; burner; a little starch; water; iodine indicator; white of egg, or other substance containing no starch.

Method. — For preparation of the iodine indicator, see No. 110, on Food Tests. Boil a little starch in water in the test tube, then add the iodine indicator. The deep blue color is the test for starch. Any substance containing starch, when boiled, will show the deep blue color if an iodine solution is added. Place a little of the white of egg in the test tube, after you have thoroughly washed it, and again make the starch test. The failure of the test in this case will emphasize the value of the starch test; you must explain, of course, before you make the test, that white of egg has no starch.

No. 109. PHOTOSYNTHESIS[1]

Materials. — Leaf of the nasturtium, wild mustard, cabbage, kale, or any member of the radish family; pan of water; burner; alcohol; iodine indicator (see No. 110); cork; knife; two pins; evaporating dish or test tube; stirring rod. Denatured alcohol does as well as grain, and costs much less. Do *not* use *wood* alcohol, as the fumes are injurious.

Method. — Cut two thin disks from the cork, and placing one disk on each side of a leaf, opposite each other, thrust two pins through both disks and the leaf, leaving the leaf on the plant. Expose the plant to the direct sunlight for as many

[1] This experiment contains material suggested by Prof. A. R. Sweetser, and is included by his permission.

hours as possible; the part of the leaves between the disks will receive no sunlight, while the rest of the leaf will. When the sunlight is no longer falling upon the plant, pick the leaf, remove the cork disks, and boil the leaf in the pan of water. Extinguish the flame, and place the test tube or the evaporating dish, partly full of alcohol, in which the boiled leaf has been placed, in the hot water in the pan. Since the boiling point of alcohol is so much lower than that of water, the alcohol will boil, removing the chlorophyll from the leaf. When the leaf is white, or very nearly so, remove it with the stirring rod, and, having emptied the alcohol from the evaporating dish, place the leaf in it, and pour over it the iodine indicator. Leave the leaf immersed for a few moments, then remove it. The leaf will be blue everywhere, excepting the round spot which was covered by the disks. The students will be able to see for themselves that the plant leaves contain starch, and that the greater the amount of direct sunlight falling upon the leaves, the greater is the amount of starch.

Discussion. — 1. Late afternoon, because it has had the sunlight all day. The plant is all the time using up the starch it makes, but it can make it only during the daylight, and, therefore, in the early morning the leaves contain little starch.

2. Sunlight.

3. The green chlorophyll absorbs the energy from the sunlight, and this energy in some unknown way breaks up carbon dioxide and water into their elements (carbon, hydrogen, and oxygen), which immediately combine to form new compounds of carbon, hydrogen, and oxygen, called carbohydrates. Only green plants contain chlorophyll and are thus able to manufacture their own starch.

4. See Answer 3.

5. The starch and sugar (carbohydrates) which are manufactured in the green leaves may be transported into various living parts of the plant and used as food, or they may be made into proteins, by the addition of some compounds of nitrogen, phosphorus, and potassium, or other substances which have entered the plant through the roots; the proteins likewise

are used as food by the plant. Excess of food supply, over and above what the plant needs for itself, may be stored in nearly any plant structure. This excess food is usually, though not always, stored in the form of starch.

6. A dependent plant lives upon the starch manufactured by some other plant, since it cannot make its own. Plants or animals which live in or upon other living plants or animals are called parasites; plants which secure their food from decaying animal and vegetable matter are called saprophytes.

7. The manufacture of carbohydrates from water and carbon dioxide through the action of chlorophyll in green plants, the energy being supplied by sunlight

8. Factory: green part of plant; machinery: chloroplasts (the chloroplasts or chlorophyll bodies are very small bodies, usually inside the leaf cells, and contain the chlorophyll); energy: sunlight; raw material: carbon dioxide and water; finished product: carbohydrates (sugar, starch); waste product: oxygen.

9. Boil the seed, and place some iodine indicator upon one of the cotyledons, or parts of the seed. The blue color will indicate the presence of starch.

10. If the green color were present in the leaf, it would be difficult or impossible to get a sufficiently positive blue test to determine whether the leaf contained starch or not.

11. The oxygen which is freed in the process of photosynthesis "is a principal factor in maintaining the oxygen supply that is so necessary to the life of animals."[1] Since animals cannot manufacture food themselves from carbon dioxide, water, and the various other raw materials, and since they cannot live on these raw materials alone, but require the finished product, they are totally dependent upon the process of photosynthesis for their food.

12. Soak the cloth with alcohol to dissolve the chlorophyll.

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[1] Bergen and Caldwell, *Practical Botany.*

No. 110. HOW TO DETECT CERTAIN IMPURITIES IN FOODS

Materials. — Test tubes; white of egg; sugar.

I. Starch. For starch indicator, iodine dissolved either in water or in alcohol (tincture) is efficient, but a solution of potassium iodide saturated with iodine is more delicate.

II. A little glucose. It is best to buy the A Fehling solution and the B Fehling solution ready-made. The formulæ for them, however, are: (A) about 35 g. copper sulphate (blue vitriol, $CuSO_4$) in 500 c. c. water; (B) 173 g. Rochelle salts (potassium sodium tartrate, $KNaC_4H_4O_6$) and 71 g. caustic soda (sodium hydroxide, $NaOH$) in 500 c. c. water. For use, mix these solutions in equal volumes. Fehling solution tablets may be obtained from the druggist.

III. A little milk or cheese; nitric acid (HNO_3), and ammonium hydroxide (druggist's ammonia, NH_4OH).

IV. Sheet of paper, cheese, or a little grease.

Method. — I. Boil a little starch in water, then add the indicator. A deep blue color is the test.

II. Add a little water to the glucose, heat until dissolved, then add equal parts of the A and B Fehling solutions, and again heat to the boiling point. Presence of grape sugar is indicated by a final change to deep brick red, through first green, then yellow.

III. Boil a little cheese in water, or boil a little milk, and add a little nitric acid. A yellow color will result which will change to orange when ammonium hydroxide is added.

CAUTION: *Do not add much ammonium hydroxide at a time as violent effervescence results when the acid and ammonium hydroxide meet.*

IV. Show that grease causes a translucent spot when rubbed upon paper. Parallel with each of the above tests except the last, make exactly similar tests upon foods which do not contain the substance tested for. Tell the class that these foods do not contain the substance tested for, and ask them to note the

difference in the behavior of the indicator. With the starch and sugar tests, use white of egg; with the protein test, use sugar.

No. 111. TESTING FOODS FOR CERTAIN IMPURITIES

Materials. — For starch tests, beans, peas, potatoes, corn, etc., are excellent. Place the indicator upon the surface of the food after it has been boiled. The blue color will show plainly. Fruit jellies and orange juice show the grape sugar test clearly. Peanuts or other nuts, fat meat, sunflower seeds, etc., will show the fat test if rubbed upon the paper. Cheese, milk, meat (small bits), etc., show the protein test clearly. In each case proceed as explained in No. 110. These are only a very few examples of the many foods which will show the different tests. It will be found interesting to test different samples of the same kind of food, as for instance, the pea or bean, for all the above materials.

Answers. — **1.** Food is a substance which furnishes or releases energy and forms material for the repair and growth of an animal or plant.

2. Carbohydrates, proteins, fats. Sugar and starch are not listed separately here, as both are carbohydrates, that is, substances made up of carbon, hydrogen, and oxygen, having always twice as many H atoms as O atoms.

3. Minerals in water release no energy for the body's use. Minerals aid digestion, however, and form bones and teeth. The beating of the heart, muscular contraction, and the ability of nerves to do their work are due to very small quantities of salts in the body.

4. Roots, such as carrots; tubers, as for instance, potatoes; bulbs, such as onions; seed, such as wheat.

5. Cellulose, a carbohydrate composing most of cotton and a large part of wood, is of use in clothing, building, explosives, etc.; gums, also, are useful carbohydrates.

6. Bread contains much carbohydrate and protein, but little fat; the butter supplies the fat. Beans, similarly, need the fat supplied by pork to make a balanced ration. Cheese is rich in all three of the important food substances, but since the

carbohydrate should be in about the proportion of four to one as compared with fats and proteins (some authorities give this proportion: protein, 1; fat, 3; carbohydrates, 6), the cracker helps to balance the ration. Interesting further elementary study in dietetics can be made from the colored charts on *The Composition of Food Materials*, which may be obtained from the Department of Agriculture at Washington.[1] The tables in *The Chemical Composition of American Food Materials*[2] by Atwater and Bryant will also prove valuable.

7. Auto-intoxication is produced when too much meat or nitrogenous food is eaten. The poisonous waste materials harmful to the body, produced when one eats more protein than is needed, must be removed by the liver and kidneys, which, therefore, are subjected to a strain through overwork.

8. That food is best which in its composition most nearly approximates the chemical composition of cell protoplasm. Milk does this better than any other food. Aside from the fats, proteins, and carbohydrates, milk contains much mineral matter, valuable for bone building. Milk is, therefore, an excellent food for infants, but it does not contain the food principles in the right proportion for an adult, and hence would not serve a grown person as a steady diet. Skim milk is better than cream, since it contains all but the fat.

9. Fat is the best heat producer of all the foods.

10. See definition of food, above.

11. (1) Thorough cooking kills harmful bacteria and other parasites, as the trichina and tapeworm. (2) Cooked meat is more completely, though less easily digested than raw meat. Heat coagulates the proteid and this must be softened or liquefied again by the digestive processes. (3) Cooking softens and loosens the fibers, making mastication and the action of the digestive juices more effective. (4) Cooking improves the flavor and makes the meat more appetizing.

[1] Department of Agriculture, Washington, D.C. Price, one dollar per set of fifteen.

[2] Experiment Station Bulletin 28, Superintendent of Documents, Washington, D.C. Price, ten cents in *coin*.

12. Cooking vegetables causes the starch grains to swell, breaking open the indigestible cellulose walls, and presenting a greater amount of surface to the digestive juices.

No. 112. THE CELL[1]

Materials. — Compound microscope, clean glass slide, and cover glass; onion bulb; a stain made by dissolving a package of pink cloth dye in as little cold water as possible; medicine dropper or fountain-pen filler (new); tumbler of cold water.

Method. — Place a little of the very thin skin found between the layers of the onion bulb, flat upon the glass slide; add a drop of water by means of the medicine dropper, and place the cover glass over it. By means of the dropper, add a drop of the dye solution at the edge of the cover glass. As it spreads under the cover glass, it will color the nucleus and nucleolus so as to make them visible. It is best to have the slide prepared, stained, and focused under the high power of the microscope before the class assembles. When the class is called, allow the students to examine the slide through the microscope, telling them what to look for to see the nucleus, nucleolus, cell, cell-wall, cytoplasm. (See Fig. 91.)

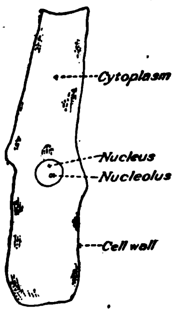

FIG. 91 (S).

The questions in the Discussion may suggest other topics of interest. To be of maximum value, this experiment should be followed later by No. 126, on protozoa.

Answers. — **1.** All plant and animal tissues which make up the organs are composed of cells.

2. " The size of cells varies from $\frac{1}{25000}$ of an inch in diameter to two inches, the average diameter being about $\frac{1}{3000}$ of an

[1] This experiment is suggested by Prof. A. R. Sweetser, and is included in this book by his permission.

inch."[1] Some protozoa (single-celled animals) are too small to be seen with the most powerful microscope, and the largest, a parasite which lives in the alimentary canal of the lobster, is about two-thirds of an inch long.

3. "... the work of an organ is really the result of the combined work of all the cells which make up its tissue. The contraction of a muscle is in reality due to the contraction of every cell of which the muscle is composed."[1]

4. "A cell never grows beyond a certain maximum size. When this is reached, the cell may divide into two new cells through an equal division of the nucleus and the rest of the protoplasm. Then each resulting cell may grow again to the maximum size of its kind, when division may take place again. Thus from one cell, many cells may result by repeated cell division. This process is the usual method of growth observed in the tissues of plants and animals."[1]

No. 113. LEAF STUDY

Materials. — Pansy, rose, apple leaf, or other stipulate leaf or leaves; maple, geranium, nasturtium, or other palmately veined leaf; lily, daffodil, grass, false Solomon's seal, fairy bell, or other parallel-veined leaf; elm, poplar, or other pinnate leaf (all fruit trees of the temperate zone have pinnate leaves); horse-chestnut, rose, clover, or other compound leaf.

Method, Conclusions, and Discussion.

1. The broad, thin, green part of the leaf is the *blade*. (See Fig. 92.)

2. The stalk which connects the blade with the plant stem is the *petiole*.

3. At the base of the petiole are sometimes two small leaf-like appendages, which are the *stipules*.

4. The daffodil leaf and the grass leaves are not petiolate.

5. Only the pansy, elm, rose, clover, geranium, and apple leaves, among those specifically named above, have stipules.

[1] Pease, *General Science*.

6. (1) The petiole offers support to the blade, and (2) in the case of many climbing plants, either the petiole itself, or a modified petiole (*tendril*) clings around the support, being thus able both to hold on firmly and to keep the blade presented to the sun; (3) green petioles may take part in food manufacture.

7. Most of the respiration of the plant is done through the stomata, usually on the underside of the blade; photosynthesis is carried on in the blade, for the most part.

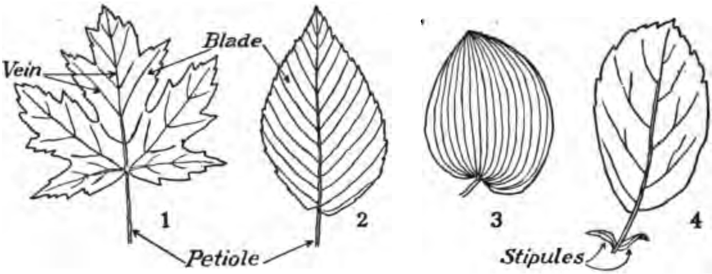

FIG. 92 (S).

1. Palmate (maple).
2. Pinnate (birch).
3. Parallel (wild lily of the valley).
4. Stipulate (Pinnate) (apple).

8. A compound leaf is one in which the petiole supports a blade consisting of several leaflets.

9. See Materials above.

10. Pinnate means resembling a feather in structure. Usually in pinnate-veined leaves, the smaller veins run out from the big central vein of the blade.

11. A palmately-veined leaf is one in which the principal veins radiate from the point where the petiole joins the blade.

12. In parallel-veined leaves the veins run parallel to each other, or nearly so. Here it may be well to mention that palmate and pinnate are both called net-veined or reticulate, to distinguish them from parallel-veined leaves.

13. Parallel, for the most part, indicate monocotyledonous plants; a common exception is the trillium, which is a monocotyledonous plant, though net-veined or pinnate-veined.

Pinnate-veined plants are commonly dicotyledonous, but the oyster plant, which is parallel-veined, is an exception.

14. Thorns; a sharp cutting edge; a bad odor; a bitter, repugnant taste.

15. Thick-walled epidermis; stomata or stomates (singular, *stoma*), minute pores in the epidermis; a coating of dead, air-filled hairs upon one or both leaf surfaces; reduction of leaf surface as in the case of spines, like the cactus; scale-like or other small, narrow kinds of leaf; several layers of palisade tissue, the outer layers lacking chloroplasts, etc.

16. Sun-dews; Venus's fly trap; pitcher plants. All catch their prey by means of specially modified leaves.

17. Carnivorous plants are usually either air or bog plants, whose roots find it difficult to secure nitrogenous matter. Animal food is so rich in this necessary food material, that carnivorous plants possessing the ability to secure animal food have a much better chance of surviving than bog and air plants which are not so equipped.

An interesting additional demonstration in connection with leaf study is to remove the chlorophyll from a mustard, nasturtium, or cabbage leaf, etc., by the method explained in No. 109. When the white leaf is then held to the light, the veining may be very plainly seen.

No. 114. OSMOSIS

Materials. — (I) Fresh egg; pin; piece of small-diameter glass tubing 3 or 4 in. long; piece of wire; paraffin; molasses; water; beaker; or (II) thistle tube; parchment paper; string; molasses; water; beaker or tumbler.

Method. — I. Crack the large end of the egg carefully and remove the shell, a bit at a time, with the pin, from a portion of the egg as big as a nickel, being careful not to break the membrane. Similarly, remove the shell from a smaller portion of the sharp end of the egg, and pour out the contents of the egg.

Fill the empty shell with molasses diluted half with water, warm a piece of paraffin the size of a big marble, and stick the tube through it. Then heat the wire and stick the paraffin and tube to the sharp end of the egg, over the hole, using the hot wire to melt and stick the paraffin and tube. Be sure that the membrane in the larger end remains unbroken, else the experiment will fail. Partly fill the tumbler with water. The egg should be all ready before the class assembles. When class is called, explain fully what has been done with the egg, place the egg in the tumbler and leave it overnight. (See Fig. 93.) The class can draw the figure and write up the method, during the remainder of the period. By the next meeting of the class, the liquid will have risen perceptibly in the tube, and the water in the tumbler will show a decided color, indicating that water has passed into the egg, through the membrane, and that molasses has passed through in the opposite direction, both seeking a point of less concentration. Osmosis tends to equalize concentration.

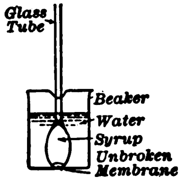

FIG. 93 (S).

II. This experiment may be more simply performed by stretching the parchment paper tightly over the end of the thistle tube, and tying it so that no liquid can leak in or out. Fill the thistle tube with dilute molasses, and place it in the tumbler of water. The same results will be noted as with the egg. (See Fig. 94.)

Answers. — **1.** Minerals in solution in soil water pass by osmosis through the permeable root walls into the plant roots, going always to a point where the concentration is less.

2. By osmosis.

3. When considerable quantities of salt are placed upon the ground, the *concentration* of water in the plants becomes greater than the *concentration* of water in the ground, and hence water passes by osmosis from the plant to the soil and the plant dies from lack of water. Some salt, also, passes by osmosis

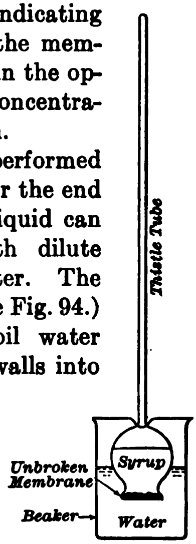

FIG. 94 (S).

into the plant and tends to drive the cell protoplasm toward the middle of the cell and away from the cell-walls, thus preventing interchange of material between cells.

4. The O, CO_2, and digested food obey the law of osmotic pressure and travel to the point of less concentration in each case.

5. Diffusion (see Nos. 37 and 38).

No. 115. TRANSPIRATION [1]

Materials. — Stem of a potted plant, upon which are several leaves (choose a stem a very little larger in diameter than the holes in the rubber stopper); bottle with two-hole rubber stopper; bent glass tube, as shown in Fig. 95; brass tube, into which the stem of the plant will go, and which has a slightly larger diameter than the holes in the stopper (a brass cork-borer is just the thing); water; tumbler.

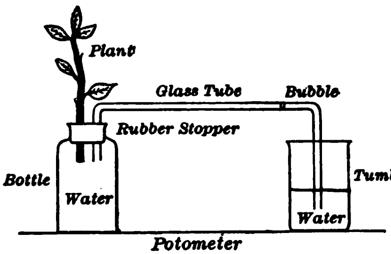

FIG. 95 (S).

Method. — Through the bottom of the stopper insert the cork-borer through one of the holes, and insert the plant stem through the top of the stopper into the brass tube. Now, when the tube is withdrawn, it will leave the plant stem tightly fitted into the stopper. It is not possible, without breaking it, to thrust a stem through the hole in the stopper. Into the other hole, insert the glass tube. When the class assembles, fill the bottle entirely full of water, and insert the stopper. Force the stopper in until the water from the bottle has almost completely filled the tube.

[1] This experiment was suggested by Prof. A. R. Sweetser, and is included in this book by his permission.

Place the other end of the glass tube in the tumbler full of water, leaving a bubble in the tube, where the water from the bottle does not quite fill it. (See Fig. 95.) Call attention to this bubble, which will at once begin to move along the tube toward the bottle, showing that water which is being taken up and evaporated by the plant is being replaced from the tumbler.

Transpiration may be shown, though less satisfactorily, by placing a small potted plant in a rubber or paper bag, binding the top of the bag tightly around the plant stem at the bottom, then weighing plant and bag, as it is, on accurate scales. Place a tall bell jar over the entire plant. After a time, vapor will have collected upon the inside of the bell jar, indicating evaporation from the plant. The plant and bag, if again weighed, will be found to be lighter than before.

Answers. — **1.** The egress or effluence of watery vapor from the parts of plants aboveground, mostly from the leaves. Transpiration pressure is the current of water passing through the plant.

2. Plants transpire the moisture faster than they are able to secure it from the soil.

3. Less surface is exposed for evaporation, hence the transpiration from the plant is less.

4. Newly transplanted trees do not have the normal amount of absorbing root surface. Leaves would soon grow in such numbers upon unpruned branches, that the tree would transpire the water faster than it could be supplied by the roots.

5. Water should be supplied in abundance, so that the plant may secure all it needs during the time in which it is regaining the normal root absorbing surface.

6. See Answer 4, No. 93.

7. (1) Keeping the plant cells filled and distended, thus preventing drooping; (2) carrying the necessary minerals into the plant in solution; (3) supplying water necessary for the manufacture of carbohydrates. Proteids are manufactured by the plant from the carbohydrates, and nitrogen, sulphur, and phosphorus.

8. The minerals which enter the plant in solution are so

dilute that great quantities of water have to be taken in before the required amount of minerals can be secured by the plant.

9. There is little transpiration from the small amount of leaf surface. The desert soil furnishes so little water that ordinary plants not specially adapted as the cactus is, could not live.

10. This question may be worked out as a separate experiment if desired. Of two rubber plant leaves, mullein leaves, or other large leaves, of as nearly the same size as possible, coat the top surface of one, and the under surface of the other, with vaseline. Place one leaf upon each pan of a balance and add weights until perfect balance is secured. After an hour or so, the pan upon which the leaf with the upper surface covered, and which, therefore, must have its evaporation taking place entirely from the lower surface, will be higher than the other, showing that it has lost the greater quantity of water. This conclusion, however, is not universally true, for some leaves have stomata on both sides through which the water is transpired.

No. 116. RESPIRATION OF PLANTS (O)

This experiment should be preceded by No. 67, on Oxygen.

Materials. — Battery jar, or aquarium, or large beaker; glass funnel; test tube; green water plant such as pond scum;

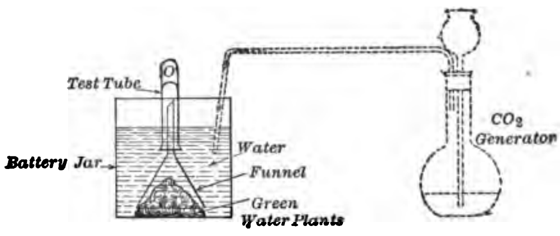

FIG. 96 (S).

water; direct sunlight; splint; carbon dioxide generator (see No. 75).

Method. — First charge the water strongly with carbon dioxide (see No. 75). This is done to promote photosynthesis

in the plants. Arrange the apparatus as indicated in Fig. 96. The test tube must be full of water to begin with, and the O given off displaces this water. Place the battery jar when ready in a window where there is very strong sunlight. Next day, take the test tube of gas which the plant has given off, and thrust a lighted splint into the mouth of it. The vigorous burning of the splint will indicate to the class that O has been given off by the plant.

No. 117. RESPIRATION OF PLANTS (CO_2)[1]

This experiment should be preceded, somewhere in the course, by No. 75, on Carbon Dioxide.

Materials. — Two large-mouth quart fruit jars with covers; a little rich sandy soil; two bean seeds, which have been soaked for about 12 hr.; two test tubes of clear limewater. (Small, slender tumblers, such as whisky glasses or measuring glasses, are even better than test tubes.)

Method. — Put a layer of damp soil about 2 in. deep in the bottom of each jar, plant one or two of the seeds in one jar, near one side. Place the jars in a warm, sunny window. In a few days the seeds will have sprouted, and in a few more days, they will be lusty plants. Now put the tumbler of limewater into each jar; screw on the cover tightly, and replace the jars in the window. Conditions are now identical in both jars, except that in the second jar there is no plant. The limewater beside the plant will become cloudy in a short time.

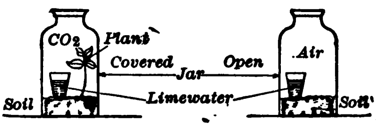

FIG. 97 (S).

This experiment has the added advantage of affording an interesting study in seed germination, and proves to every student that carbon dioxide is given off by a growing plant,

[1] This experiment was suggested by Prof. A. R. Sweetser, and is included in this book by his permission.

for the jar without the plant does not contain sufficient gas to affect the limewater.

Answers. — **1.** The air is in solution in the water.

2. (1) Some of the O taken in was not needed by the plant, since the action took place in direct sunlight, and was passed out again; (2) some was a by-product from the manufacture of starch by the plant.

3. Plants give off O, which assists in keeping the water oxygenated; fishes give off CO_2, which is needed by the plants in starch manufacture (photosynthesis).

4. Plants use some of the O in oxidizing food materials to secure energy, just as any other organism does, and a little more is used in the manufacture of starch and sugar. In direct sunlight, however, more O is manufactured by the plant than is needed by it.

5. Water, CO_2, and O.

6. Had the experiment been performed in darkness, the results would have been different: the plants are using O all the time, and it is only when in direct sunlight that they manufacture more O than they need. An interesting further experiment may be made out of this question. Using the apparatus as in No. 116, note the amount of O evolved by the plant during several hours, and then place the plant in a dark room for several more hours. It will be seen that no more O has been given off by the plant, and hence the students will see that direct sunlight is necessary to the success of No. 116.

7. Stomata (openings in the leaves), lenticels (openings in the bark of the stem), and roots.

8. Photosynthesis.

9. Green plants use much CO_2, and at the same time give off much free O.

No. 118. STUDY OF THE PARTS OF THE FLOWER

This experiment is intended as an introduction to sex hygiene and affords a logical approach to this subject. The experiment should later be followed by one or more upon the development of animals, such as the chick, the frog, the mosquito, and the fly. (See Nos. 132, 133, 134, and 135.)

Materials. — A simple flower such as, for instance, the wild mustard, sage, sweet briar. If time permits, select several different simple flowers for comparison.

Method. — Point out in turn the sepals, petals, stamens, and pistil. (See Fig. 98.) Emphasize the grouping of the flower parts into the *floral envelope*, consisting of calyx and corolla, and the *essential organs*, stamens and pistils. Make the following explanations: Reproduction is the most important function of every living organism or creature, and all creatures exist primarily for this purpose. Many plants put practically all their energy and food into producing seeds, and often give up their lives in developing their seeds. Mention as an illustration of this last statement, that the foliage of many common garden plants dies when the seeds begin to form; many animals, likewise, as for example the salmon, die practically as soon as the eggs are laid (numerous examples from insect life have been noted).

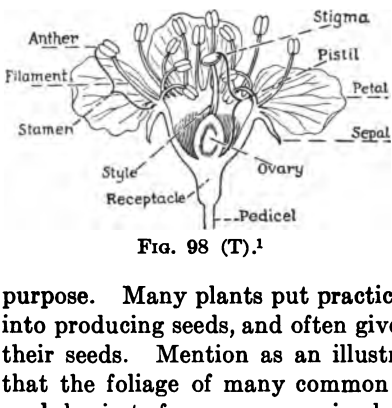

FIG. 98 (T).[1]

All living creatures, plant and animal, reproduce by the union of a male and a female element. The male element is called the sperm cell; the female element is called the egg cell. In the flower, the sperm cells are found in the form of pollen grains and are inclosed in a sac-like structure, called the anther, which occurs at the tip of the stamen, while the egg cells are found in the form of ovules and are inclosed in the ovary at the base of

[1] Pease, *General Science.*

the pistil. Thus the stamens represent the male element, the pistil, the female element. The pollen grains are deposited on the stigma of the pistil and ultimately fertilize the ovules as explained more fully in Answer 2 below. From the fertilized egg cell, the seed, which contains the embryo or baby plant, is developed. The embryos of all animals are developed in much the same way, by union of sperm cell and egg cell to form a fertilized egg cell. The embryo plant is incubated in the ground; the embryo chicken is incubated outside the body of the hen, though the egg is fertilized inside; the embryos of most of the higher animals are incubated inside the body, where the egg is fertilized.

This explanation has been found very successful with beginning, mixed high-school classes. By approaching this important subject of sex and reproduction through the flower, all embarrassment and self-consciousness on the part of the student are eliminated, and he gets the *facts* in a wholesome way.

The principal parts of a complete flower are the stamen, pistil, corolla (composed of the petals), the calyx (composed of the sepals), the receptacle, and the pedicel. The stamens are grouped around the pistil which is in the middle, while the petals and sepals are grouped around the stamens, the sepals being usually outside the corolla. (See Fig. 98.)

Answers. — **1.** Solely for the purpose of reproduction.

2. Pollination, maturation, fertilization, segmentation, and differentiation. *Pollination* is the transfer of the pollen from anther to stigma. The fertilization is seldom effected by pollen from the same flower, but is usually brought about by pollen from another flower, carried by the wind, by insects, or by birds. In the process of *Maturation*, the pollen grain does not itself descend to the egg cell, but develops a tube through which the nuclei of the male element descend to some one of the ovules in the ovary. *Fertilization* is the union of the pollen nuclei with the nucleus of the egg cell. *Segmentation* is the development of the embryo, through repeated divisions on the part of the fertilized egg cell. The embryo is complete in every respect before the seed is planted. *Differentiation* is the development

of the uniform plant cells, which have arisen, as a result of segmentation, into different types of cells which ultimately form root, branch, etc.

3. To insure pollination, and also for greater protection.

4. The mature seed of the plant and the egg of the bird represent the same stage in the growth of the individual. They are resting stages which aid the species to survive in the struggle for existence.

5. A complete flower must have calyx, corolla, stamen or stamens, and pistil; a perfect flower has only stamens and pistil.

6. A hermaphroditic plant has both the male and female elements in the same flower; many lower animals, such as, for instance, some snails and the earthworm, are hermaphroditic. Monœcious plants have the stamens and pistils in different flowers on the same plant, as for instance the cottonwood. Diœcious plants have male and female flowers borne on separate plants, as for instance, the holly, the hop, hemp, pussy willow, hazel, etc.

7. Fern, mushroom, alga, moss, yeast, mold, bacterium.

8. Spores.

9. A composite flower is composed of a large number of perfect and often complete flowers, grouped together. The sunflower is a good example, as are also the dandelion, daisy, and oyster plant. If you have access to a good compound microscope, the class will be much interested if you show them that each of the little "tufts" in the center of the composite flower is itself a perfect flower. Each of the large petals around the edges of the flower is part of a flower also.

Most of the above questions are included in case it is desired to go into flower study more deeply than is usually undertaken with a beginning class in science.

No. 119. STUDY OF A PLANT EMBRYO

Materials. — Several large beans such as lima or scarlet runner bean seeds.

Method. — Soak the beans in water overnight, then remove the outer or seed coat from the beans, and halve them, in order to display to the class the different parts of the embryo bean. (See Fig. 99.) Point out the two fleshy halves or cotyledons, the little sprout or hypocotyl, and the plumule, which comprises the two tiny folded leaves. Point out the lower end of the hypocotyl, telling the students that this will develop the root.

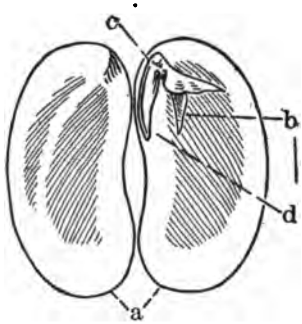

FIG. 99 (S).[2]

a, Cotyledons; *b*, Plumule; *c*, Hypocotyl; *d*, Tip from which root develops.

Discussion. — **1.** Dicotyledon.

2. Monocotyledon.

3. See Question 13, No. 113.

4. "Proteins of many kinds; carbohydrates in the form of starch, sugar, or cellulose; and fats or oils."[1]

5. The seed coat protects the embryo from mechanical injury, and protects the endosperm also when it is present. A good example of the endosperm is all the grain in the corn grain, except the oval-shaped body or cotyledon.

6. In hard-shelled nuts, there must be a softer-walled part through which water can enter, in order to allow germination to begin.

7. "(1) The proper temperature. (2) Enough moisture. (3) Air or oxygen. (Some seeds begin to germinate without air, but soon die unless it is supplied to them.)"[1]

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[1] Bergen and Caldwell, *Practical Botany*.

[2] Pease, *General Science*.

No. 120. SPORE PRINT

This experiment is a very superficial one from a scientific point of view, but it is intended to arouse interest in the mushroom family, and by means of the Discussion to emphasize some of the most important facts regarding mushrooms, and to correct some of the popular errors regarding them.

Materials. — Two or three large specimens of *any* flat-topped gilled mushroom, such as the common meadow mushroom (white-gilled) or the genus Agaricus (pink-gilled or dark brown-gilled); soup plates; sheets of paper of two or three different colors; puffballs in different stages of ripeness.

Method. — To make a "spore print," remove the stems from the caps and place the caps, gills down, upon the sheets of paper. Different colors of paper are used because the spores are of different colors for different species, and may not show up well on some colors. Invert the soup plates over the caps, and leave them until the next day. When the plates and caps are removed, the outlines of the gills will be found to be reproduced by the spores upon the paper. Select, if possible, three specimens of puffball, one fresh, with the meat white; one beginning to mature, with the meat yellow or brown; one entirely ripe, and open, with the spores emitted as a puff of smoke whenever the puffball is squeezed. Show all three stages to the class. The class will be able to decide that the spores of the gilled mushroom are located in the gills, while those of the puffball are located in the ball, which has to open before the spores can escape. In both cases the spores, being so very small, are carried by the wind, and are thus scattered broadcast.

Answers. — **1.** None. All are mushrooms; the correct distinction is between edible and non-edible mushrooms.

2. Not all mushrooms are edible; authorities differ regarding the number of edible species, but with careful study anybody may learn to recognize six or more delicious edible mushrooms, and specialists claim to know as many as a hundred or more. Any locality in which mushrooms are common may have over two hundred species of mushrooms and fungi.

3. Several members of the Amanita family are deadly poisonous. Emphasize this fact. To quote from Bulletin 175, United States Department of Agriculture: "Too emphatic a statement cannot be made as to the absolute impossibility of 'telling the difference between mushrooms and toadstools' by any of the so-called tests. It is well to look with suspicion upon every mushroom which is not positively known to be edible."

4. None. Emphasize the fact that the "peeling," "silver spoon," and other tests are *entirely unreliable.*

5. This question is put in to stimulate curiosity regarding the different species. The students may be encouraged to bring in different species. They may find examples of mushrooms with little tubes instead of gills, or with pits containing the spores on the surface, or specimens that look like coral, etc.

6. Fall, after a rain, is the best time during the school year to study mushrooms, but they last often until December, and may also be found during the spring and into early summer, but probably less plentifully.

7. On lawns, in fields, in the woods, around rotting stumps, sometimes on trees, around manure heaps, etc.

8. (1) Choose only specimens that you *know* are edible. If you pick any doubtful specimens for study, be sure to put them in a sack by themselves, and do not put them into the same basket or near the edible ones. (2) *Choose only fresh specimens.* This cannot be too strongly emphasized. (3) Discard all specimens infested with insects. You may have to break open the cap to ascertain this.

9. Authorities differ regarding how good a food the mushroom is: some say as good as meat, and call mushrooms "vegetable meat," while others say that in food value the mushroom is only about as good as cabbage.

10. From the Government.[1] It will pay you to get this bulletin before beginning the mushroom study with the class.

11. Saprophytes, plants which live upon dead animal and

[1] Bulletin No. 175, *Mushrooms and Other Common Fungi*, United States Department of Agriculture, Washington, D.C. Price, thirty cents in coin.

vegetable matter, as distinguished from parasites, which live in or upon living animals and plants.

12. Mosses, ferns, molds, yeasts, bacteria, etc. An interesting demonstration can be made in connection with this question, provided you have access to a good compound microscope. Select a ripe sword fern, one with the little indusia (the spots on the under side of the fronds) entirely brown, and pick off one or two of these little brown spots. When placed under the low-power lens, the little sporangia, or sacs containing the spores, may be seen to break open in great numbers, scattering the spores. The class will be delighted with this.

No. 121. YEASTS[1]

Materials. — Two Florence flasks or test tubes, one fitted with a one-hole rubber stopper and glass or rubber delivery tube as in Fig. 100; a little molasses or glucose; a cake of compressed yeast (Fleischmann's is excellent); water; clear limewater.

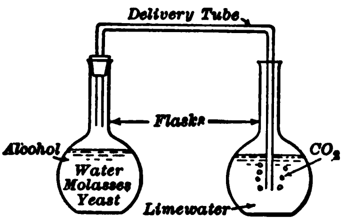

FIG. 100 (S).

This experiment should be preceded somewhere in the course by the experiments on carbon dioxide, Nos. 75 and 77.

Method. — Fill the flask half full of water, and add a tablespoonful or so of molasses, and a little of the yeast cake. Connect up the apparatus as shown in Fig. 100, with the other flask partly filled with limewater. Put the apparatus in a warm place until next day, when it will be found that a considerable fermentation has taken place, and the limewater will have been colored white by the action of the carbon dioxide, forming calcium carbonate. The yeasts produce enzymes or ferments, which break down the sugar in the solution

[1] This experiment is based upon material taken from Conn, *Bacteria, Yeasts, and Molds in the Home.*

to form alcohol and carbon dioxide. Allow the class to smell and taste the fermented solution to ascertain that alcohol is present.

Answers. — **1.** The resting state as in the ordinary yeast cake; the growing state; and the spore-bearing state.

2. Yeast spores blowing around in the air are called wild yeast, to distinguish them from the cultivated varieties, such as those that are in yeast cakes.

3. "The apple has been growing in the air for many weeks, and the wild yeasts have had plenty of chances to lodge on its skin. When the juice is squeezed from the pulp, it is sure to contain these yeasts, and they promptly start a fermentation."[1]

4. ". . . wild yeasts do not . . . live permanently in the air, since the air would itself furnish no food for them. They live and grow in the soil, in decaying fruit on the ground, on the surface of fruit on the trees, and in a variety of other places. The air simply distributes them."[1]

5. Sugar. All natural sugar solutions, such as fruit juices, are suitable for the growth of yeasts, because they contain the other things besides sugar which these plants need.

6. "A high percentage of sugar is injurious to the growth of yeasts, a fact that explains why almost anything can be preserved if it is saturated with a large amount of sugar."[1]

7. Principally for bread-making.

No. 122. MOLDS[2]

Materials. — Fifteen saucers or other dishes which may be placed in pairs, one being the cover for the other; two tumblers; bread.

Method. — I. In one saucer place a piece of moistened bread, and in another, place a similar piece of very dry bread. Leave them exposed to the air for a time, in order to get inoculated

[1] Conn, *Bacteria, Yeasts, and Molds in the Home.*

[2] This experiment is based upon material to be found in Conn, *Bacteria, Yeasts, and Molds in the Home.*

with spores from the air. Place another saucer over each dish to prevent evaporation of the moisture in the damp sample, and to make exactly similar conditions in each saucer. Place the covered saucers in a warm place for several days. It will be found that the mold grows on the damp bread and not upon the dry.

II. Place in each of three saucers a piece of dampened bread. Allow each to become inoculated as above, with spores from the air. Cover each with a saucer, place one in the coolest place you have available, outside the window if it is winter, or in the school basement; place the second in a moderately warm place, and the third in a very warm place, such as upon the boiler, over a radiator, etc. After a few days it will be found that under exactly the same conditions other than temperature, mold develops most rapidly at a moderate temperature.

III. Place a piece of dampened bread in each of two saucers, allow the bread to become inoculated, cover one saucer with another, and the other saucer with a tumbler, so that evaporation is prevented in each case, but so that the light can strike the bread in one and not in the other. Place the saucers in a sunny window where conditions are the same for both, and after several days compare the growth of mold in the two saucers. It will be found that the more luxuriant mold growth is in the dish which has been kept dark.

IV. Place a piece of dampened bread in each of two saucers, cover one with a tumbler, and leave the other open, so that there will be a free circulation of air. The conditions are now identical in each case, as far as light is concerned. Place both dishes in equal illumination, where there is free circulation of air, and during the next few days, keep the bread in the open dish damp. It will be found that the covered bread will have the more luxuriant growth of mold.

If time permits, it is interesting to place different kinds of food, such as cheese, fruit, bread, etc., all well-dampened, in a dish, allow them to become inoculated from the air, or sprinkle over them a little dust from the floor, and then cover the dish and set it aside in a warm place for a week or so, to determine

how many different kinds of mold can be distinguished. A good hand lens will assist in determining the different species, which are distinguishable by fineness of thread, rapidity of growth, and particularly by the color, which will be white, blue, green, brown, black, red, or pink. Students will be pleased with this study.

Answers. — 1. "Mold" is not a scientific division of non-flowering plants, because "under this head are included several different kinds of plants which botanists agree must be separated into several divisions."[1]

2. Higher fungi (which include mushrooms, wood fungi, rusts, smuts), yeasts, bacteria.

3. A minute parasitic fungus which frequently appears upon the leaves, stems, and other parts of plants, or other decaying organic substances as a white, frostlike down, or in spots, or with various discolorations. For the purpose of our experiment, it is sufficiently correct to call mildew a mold.

4. ". . . spores are constantly floating in the air, and . . . they may also be carried easily upon the feet of insects that chance to light upon a bit of spore-bearing mold."[1] Spores may also be implanted directly by contact of sound fruit with spore-bearing, moldy, decaying fruit.

5. "From a single decaying apple, infection may spread from apple to apple until a whole barrel speedily becomes decayed and ruined. It is an example of direct contagion."[1]

6. "Wiping cannot, indeed, wholly remove the spores, but it aids materially. Moreover, if the wiping is done with a dry cloth, it will also remove the moisture, a matter of no small importance."[1]

7. Molds assist in breaking down and decaying wood fiber, so that the materials may again be assimilated by various animals and plants. ". . . otherwise the food material of the world would in time become stored away in the form of wood."[1] A few of our foods, such as Roquefort, Stilton, Gorgonzola, and Camembert cheese, get their fine flavor from molds.

8. Ringworm and favus, a disease difficult to distinguish

[1] Conn, *Bacteria, Yeasts, and Molds in the Home.*

from ringworm. "In the case of both of these diseases the affection is spread by means of mold spores discharged through the skin. They are liable to be carried from person to person by the use of combs or towels, or even cloths and sponges used in washing or bathing the skin. If, therefore, there is an example of ringworm in a family, it is imperative, in order to prevent the spread of the disease from one to another, that the person suffering from the attack should have his own combs, his own towels, his own sponges, and even his own soap for washing. By this means the disease can usually be confined to the person in whom it originally appears. The cure of such diseases must be left to a physician."[1]

9. If food quickly becomes moldy in a pantry it "is an indication that the room is filled with mold spores in such numbers that they drop into everything exposed. The remedy for such a condition is to get rid of the spores. The room should be vigorously swept and dusted, a windy day being chosen, and all windows and doors should be left wide open to blow out the dust. After a thorough airing, the room should be closed again and left undisturbed until the remaining dust settles; then the floor, shelves, window sills, etc., should be wiped with a damp cloth. This will usually remove the spores, and food will subsequently be less liable to mold."[1]

10. Molds make food unsightly; they modify and usually injure the flavor; they produce a peculiar smell, usually musty; "in the end the growth of molds results in the total ruin of the food, since after a while mold growth produces decomposition, putrefaction, and decay. These later changes are due to the fact that the molds are consuming the material as their own food."[1]

11. By reheating the fruits to the boiling point, and then covering them tightly so that they may not become reinfected from air.

12. It is most important to keep the food dry. "If it is of a nature that will stand drying, it may be protected indefinitely if once dried and not allowed subsequently to become damp.

[1] Conn, *Bacteria, Yeasts, and Molds in the Home.*

Indeed, in a pantry or a cellar, molding commonly means excessive dampness. Sunlight and fresh, circulating air, and a low temperature check the development and growth of molds."[1]

No. 123. BACTERIA[2]

Materials. — Petri dish and cover, or any two dishes, such as saucers, one of which can be placed over the other as a tight cover; small potato; stew pan; steamer; water; knife; burner; support; a house-fly.

Method. — Wash the potato, and then cut it lengthwise, making several slices about $\frac{1}{4}$ in. thick. Place these in one saucer, and place the saucer in the steamer. Boil water in the stew pan, place the steamer containing the saucer over this boiling water, and steam the potato slices about twenty minutes in order to sterilize them thoroughly. It is essential, of course, that nothing except what is to inoculate the potato strips touch them. Allow the fly to walk over the strips, or expose the strips to a room which has been freshly swept. It will be difficult to inoculate the potato in a still room, in which there is little dust moving. After the strips have been inoculated, place the other saucer over the first one as a cover and place the two saucers in a warm (not too warm) place. Within three or four days, the bacteria colonies will have developed to a point where they are visible as white or yellowish spots upon the surface of the potato. You may also have some mold cultures on the potato strips. Emphasize the fact that bacterial colonies develop under favorable conditions into large colonies, starting from a single bacterium. Bacteria, germs, and microbes are synonymous terms.

The questions in the Discussion are only a few suggestive ones which may be assigned to be looked up outside of class and reported upon in class. Students are intensely interested in the subject of germs.

[1] Conn, *Bacteria, Yeasts, and Molds in the Home.*

[2] This experiment was suggested by Prof. A. R. Sweetser, and is included in this book by his permission.

Answers.—1. Yeasts and molds are very much larger than bacteria, which are the minutest known plants. While the variation in size between different kinds of germs is great, an average would be about .0001 in. in length and about .00002 in. in diameter. A single drop of impure water or sour milk may frequently contain several million microbes.

2. ". . . they multiply with a rapidity that is quite inconceivable; they are quite invisible to the naked eye, and their presence is not suspected until they become numerous enough to produce undesired changes in the material upon which they are growing."[1]

3. ". . . plants, although many of them are endowed with a power of motion and for this reason might readily be mistaken for animals."[1]

4. *Coccus*, spherical; *bacillus*, rod-shaped; *spirillum*, spiral in form. Some specimens of all three types possess *flagella*, hair-like appendages by means of which they move about.

5. Bacteria lengthen and divide into two, by a process called *fission*, which under favorable conditions may result in nearly seventeen million offspring from a single germ in twenty-four hours. Under some conditions, some kinds of bacteria produce a spore which can exist dormant under conditions otherwise impossible for it to live in, and when conditions again become favorable, the spore develops into the bacterium again and resumes its vital functions as usual.

6. "Some species can grow perfectly well without air (anaërobic), and others cannot grow at all if they are without contact with air (aërobic)."[1]

7. In water, air, dust, soil, upon the surface of almost every article, inside our mouths and bodies, etc.

8. "Some species can live upon simple minerals from the soil. . . . Any materials containing sugars, starches, proteids (albumen, lean meat, etc.), or other animal foods, furnish excellent nourishment for bacteria."[1]

9. In moist proteid material, kept at moderate temperatures (for most species) and in darkness. Germs thrive in dirt.

[1] Conn, *Bacteria, Yeasts, and Molds in the Home.*

10. Plenty of sunlight, fresh air, and absence of dust. Sweeping merely stirs up the dust and bacteria, only to have them fall in another place, but a dampened dust cloth removes dust and bacteria. Keep the fly from breeding and coming into the house with its load of filth and germs. Food must be heated thoroughly for at least twenty minutes in order to kill most of the bacteria. Refrigeration retards the growth of bacteria, but even freezing does not kill them; they merely remain dormant.

11. Sugar, salt, vinegar, and other spices. Formaldehyde, benzoic acid. Boracic acid and borax *may* be harmless in small quantities.

12. Germs may gain entrance to the body through any of the body openings or through a scratch or cut. We take them in along with food, water, and air; but, more usually, we "catch" diseases by direct contact with sick people, or by eating and drinking out of dishes which have not been sterilized after the patient has used them, or by handling articles the patient has used, such as soaps, combs, books, and towels. Tuberculosis.

13. Of more than a thousand kinds of bacteria, only about twenty kinds are harmful to man; the others are harmless or useful. Among the useful ones are: (1) soil bacteria which prepare food for the trees, vegetables, and grains upon which man depends for food; (2) those used in preparing certain foods, as for example, butter, cheese, cider, vinegar; (3) those which assist in certain industries, as the tobacco industry (the curing), the indigo, the flax and the hemp industries, the sponge industry (the decaying of the animal matter from the skeletons), and the leather industry (tanning); (4) decay bacteria which dispose of the dead bodies of plants and animals.

14. Molds "grow best upon acid substances; but most bacteria cannot endure acids, preferring a slightly alkaline food."[1] Hence, molds assist in the decay of acid fruits, etc., while bacteria assist in the decomposition of alkaline, plant, and animal matter.

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[1] Conn, *Bacteria, Yeasts, and Molds in the Home.*

No. 124. HELIOTROPISM

Materials. — Lusty growing potted plant, such as sunflower, heliotrope, geranium, or, better, box containing several young plants.

Method. — Place the pot if possible in a room with a single window, or at any rate so that the light from one window exerts much the stronger influence upon it. Place the plant a foot or so from the window, and allow it to remain there for a week. At the end of this time it will be evident that the plant has grown toward the sunlight. Turn the plant around now, and leave it for another week. The plant will again have turned itself so that it is growing toward the light.

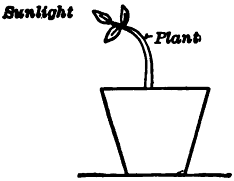


FIG. 101 (S).

This experiment may be performed, perhaps, even more satisfactorily by simply cutting a window in the side of a pasteboard box, and planting in the box several seeds, previously soaked. The seeds will germinate and the little plants will seek the window where the light enters. The same thing may be shown by placing the potted plant in a covered box which has had a hole cut in the side. In each case, of course, place the hole in the box toward the window.

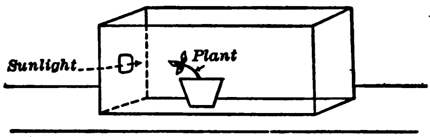


FIG. 102 (S).

Answers. — **1.** So as to present as broad a leaf surface as possible to the sunlight, in order to promote photosynthesis in the leaves.

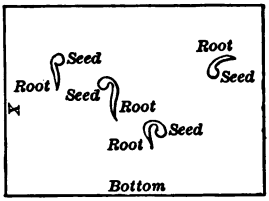
2. Photosynthesis is the process by which green plants manufacture carbohydrates out of carbon dioxide and water, through the aid of sunlight.

3. So that they will grow evenly toward the sunlight. They would soon become deformed if never turned, since they would continue to grow in the same direction, out of perpendicular.

No. 125.
SEED GERMINATION AND INFLUENCE OF GRAVITY UPON DIRECTION OF ROOT GROWTH[1]

Materials. — Two glass plates about 4 in. long by 5 in. wide; passe partout tape; a number of sheets of new blotter, a little smaller than the plates; several strips of the blotter 4 in. long by 2 in. wide; mustard seeds; fountain-pen filler or medicine dropper.

Method. — Make the "pocket garden" as follows: Upon one of the glass plates lay four or five thicknesses of blotter, and place upon the top blotter half a dozen or so of the mustard seeds, which have soaked overnight in water. Lay enough of the blotter strips along two sides of the blotter sheet upon which you have placed the seeds, so that when the second plate is placed upon the top of the narrow blotter strips, it will just touch the seeds, but will not press them too firmly. Bind the plates firmly together with the passe partout tape, using strips not quite so long as the plates, so that there will be left small air spaces at the corners. With the medicine dropper add enough water through one corner of the garden to saturate all of the blotters. The whole "pocket garden" will be perhaps ½ in. thick. It should be put together in the presence of the class, who should describe its construction in their Method. Write the word "bottom" upon one side of the garden on the tape, and put the garden away in a dark place for a couple of days, telling the class that you have put the side marked "bottom" down.



Pocket Garden

FIG. 103 (S).

At the end of two days, again display the garden to the class. The seeds will have germinated, and all the primary roots will have turned themselves so that all are growing toward the side marked "bottom." (See Fig. 103.) Let the class draw the

[1] This experiment was suggested by Prof. A. R. Sweetser, and is included in this book by his permission.

face of the garden exactly as it looks with the side marked "bottom" down, indicating the seeds with their roots represented exactly as they have grown. Mark a cross upon one of the edges of the garden for a new "bottom," and again set the garden away in the dark for another day or two, with the *new* bottom down. At the end of that time the class will see that the roots have again turned themselves and are growing toward the new bottom. Place the garden in view with the new bottom down, and let the class again draw as accurate diagrams as possible, showing the seeds and roots as they now look. (See Fig. 104.) The students will be able to infer that gravity causes the roots to grow downward.

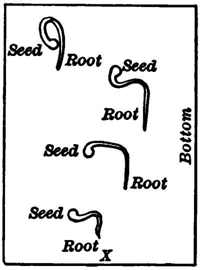


FIG. 104 (S).

It is best, perhaps, to attempt to show nothing with this experiment other than just the gravitational effect, for the study of the roots and root hairs is taken up more fully and in a way to be more easily understood in other experiments. Sometimes the seeds mold and do not germinate properly. It is, therefore, wise to make one or two other similar gardens outside of class the same day, so as to have a reserve in case the one made in class fails to work properly.

Answers. — **1.** Roots will grow towards water and around obstacles.

No. 126. PROTOZOA

This experiment should be preceded somewhere in the course by the one on plant cells, No. 112.

Materials and Method. — Pail of pond water and wisp of hay or dried grass which grew near it; compound microscope; slide and glass cover; medicine dropper or new fountain-pen filler; a little absorbent cotton. If you cannot get the pond water, place the wisp of hay in a pail of ordinary water, and the pro-

tozoa will develop, though probably more slowly and in smaller numbers. Allow the hay to remain in the water several days, until decay is obvious from the appearance and smell of the infusion. From time to time make a slide by taking with the medicine dropper a drop of the water at the surface of the pail, placing it upon the slide and covering it with the glass cover. Examine it with the low power, to see whether the one-celled animals are numerous. When they are present in sufficient numbers, make one or more slides for class study by placing a few fibers of the absorbent cotton along with the drop of

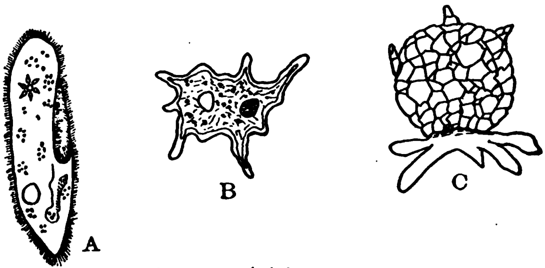


FIG. 105 (T).[1] Protozoa.

A, Paramecium; *B*, Amœba; *C*, Lobosa.

culture on the slide; then placing the glass cover over the drop, focus under the high power. The cotton fibers serve to some extent in entangling the protozoa and in hampering their movements, thus permitting them to be examined more easily. You will probably find several different kinds of protozoa in your culture, paramecia being common.

A further interesting study of protozoa is to study slides made of the same culture a week or so apart. As the conditions inside the culture change, because of the bodily functions of the animals in it, the kinds of protozoa most in evidence change likewise. Each lives its day, and then gives place to another species when conditions no longer support its own kind of life, but become more favorable to the thriving of another species. In time, if the culture is in no way renewed, all the differ-

[1] Pease, *General Science.*

ent kinds will have disappeared. This makes an interesting experiment, bringing out the influence of *environment upon life.*

Another interesting study is that of a little of the mud and slime from the bottom of a pond. Make slides of it in the same manner as described above, without the cotton, and show the most interesting ones to the students. There will doubtless be many tiny animals, higher than the protozoa in the scale of animal life, but still microscopic, which will delight the class, and make them want more science.

The questions in the Discussion are intended as interesting topics to be looked up outside of class and reported upon.

Answers. — 1. " The food of protozoa consists of organic matter both vegetable and animal. Bacteria, diatoms," *i.e.*, microscopic, single-celled algæ (plants), "and other protozoa form a large part of the bill of fare." [1]

2. Some species " do not ingest solid food, but manufacture it by means of chlorophyll " (as green plants do).[1] Some Protozoa take food in through the surface of the body at any point; others capture their prey by means of tentacles through which they suck out the juices for their own use; others possess tiny hairs called cilia which create a current in the water, and thereby bring the floating food particles into a rudimentary mouth.

3. Amebic dysentery, sleeping sickness (the parasite is transferred to the body through the bite of the Tsetse fly), malarial fever, sometimes catarrhal inflammation of the intestine, yellow fever.

4. Protozoa are common in stagnant pools and swamps, and in ocean water. They are also blown about by wind when the ponds dry up and, therefore, may be upon grass, the skin of fruit, etc. Drinking water is often colored red or yellow by them, and the sea surface is sometimes colored orange or red by vast numbers of them.

5. Most protozoa are harmless, and many are beneficial in that they serve as food for fish.

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[1] Hegner, *College Zoölogy.*

No. 127. MUSCLES

Materials. — Part of the lower leg of a beef, with part or all of the big thick muscle, with the tendon attached to the bone; knife; dissecting needle or ordinary needle; burner; stand; vessel of some sort in which to boil the muscle.

Method. — Cut off a strip of the muscle and boil it thoroughly, before class. In the presence of the class cut straight across this boiled strip. Point out the bundles which have been severed. With the dissecting needle, separate one of the bundles of muscle fibers in the boiled strip, to show the fibers of which it is composed. Point out the tough tendon by which the muscle is attached to the bone. The student will be able to infer that muscles are composed of bundles of fibers, and are attached to the bone by means of tendons. It may be well to emphasize that all muscles are not attached to bones in this way, though most of the big, external ones are.

Answers. — **1.** About five hundred.

2. It shortens and thickens, because of its contraction.

3. The longer a muscle, the farther it can contract and move a bone; but the thicker it is, the greater weight it can lift or the greater resistance it can overcome.

4. From the oxidation of digested or broken-down food products, usually carbohydrates.

5. Muscles which pull in opposite directions to each other, as, for instance, the biceps and triceps, one of which pulls the arm up and the other pulls it down.

6. "The muscles which may be controlled by the will are voluntary muscles."[1] Muscles such as those of the digestive system, which act independently of the will, are involuntary muscles.

7. Exercise develops the muscles. "Muscular exercise is necessary, not only for the development of the muscles, but also for the health of the body as a whole. When we exercise the muscles, we exercise all the other organs. The heart and the blood vessels work better. The lungs take in deeper draughts

[1] Pease, *General Science*.

of air. The appetite is increased, and the digestive system does better work. The waste products of the body are carried away more rapidly. The brain is clearer and the spirit more cheerful." [1]

8. " Exercise draws the blood to the muscles and the skin," when " the blood is needed in the digestive system." [1]

9. In games, by developing muscles and nervous response, one gains speed, accuracy, and ability to think quickly. In team games, moreover, one gains valuable training in citizenship, since selfish ends have to be sacrificed for the good of the group.

10. The gymnasium gives all-round development, as well as the special training for the development of special muscles that particularly need it, and it trains the coördinating and balancing powers of the body.

No. 128. STUDY OF JOINTS

Materials. — Secure from the butcher a hip joint and a knee joint of some animal or fowl.

Method. — Show the class how action of the hinge joint is limited to a back and forth motion, while a ball-and-socket joint permits a more nearly circular motion.

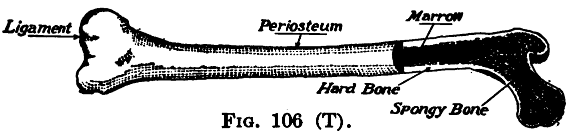

FIG. 106 (T).

No. 129. STUDY OF BONES

Materials. — Fresh, uncooked round-steak bone; large beef or mutton bone with a joint; meat saw.

Method. — Saw lengthwise through the joint of the bone and remove the lengthwise strips an inch or so long. Call

[1] Winslow, *Healthy Living.*

attention to the red and the yellow marrow existing in the bone cavities; to the periosteum, which is the tough covering of animal tissue over the bone; to the tough ligaments, which hold the joints together; to the spongy bone, which is in the end of the long bones, near the joint; and to the hard bone along the sides of the long bone.

No. 130. ANIMAL MATTER IN BONES

Materials. — Small bone of any sort, such as the rib bone of a fowl; test tube; hydrochloric acid; water.

Method. — Clean the bone thoroughly, and place it in the test tube along with the acid, diluted four parts of water to one of the acid. There will be a slight effervescent action, and carbon dioxide will be given off as the acid acts upon the calcium carbonate in the bone. After three or four days, pour off the dilute acid and wash the bone. It will retain its original shape, but since all the inorganic mineral matter will have been removed and only the animal matter in the bone will be left, the bone will be almost as pliable as rubber.

No. 131. MINERAL MATTER IN BONES

Materials. — Any bone; hot fire, preferably of live coals where there is a good draught.

Method. — Lay the bone upon the live coals and allow it to burn up as much as it will. If it is inconvenient to burn it in the laboratory, it may be done elsewhere, and the bone carefully removed and brought unbroken to the classroom. It retains its original shape but is very brittle.

Answers. — **1.** Hinge: elbow and knee; ball-and-socket: hip and shoulder.

2. Pivot joints, in which one bone rotates around another which remains stationary; an example is the joint between the first and second cervical vertebræ, which permits the head to turn from side to side. "Gliding joints. These permit as a rule but little movement: examples are found between the

closely packed bones of the tarsus (in the hand) and carpus (in the foot) which slide a little over one another when subjected to pressure." [1]

3. Chiefly bone earth or normal calcium phosphate $[Ca_3(PO_4)_2]$ and calcium carbonate ($CaCO_3$), though there are small quantities of other salts. "The inorganic matters form about two thirds of the total weight of a dried bone." [1]

4. "The organic portion (of bone) . . . consists chiefly of an albuminoid, *ossein*, which by long boiling, especially under pressure at a higher temperature than that at which water boils when exposed freely to the air, is converted into gelatin, which dissolves in hot water." [1]

5. See Method, No. 130, page 187.

6. ". . . the . . . child requires food which shall contain a large proportion of the lime-salts which are used in building up bone. Nature provides this in the milk, which is rich in such salts, and no other food can thoroughly replace it. . . . Many children, who are given food abundant in quantity, are really starved, since their food does not contain in sufficient amount, the mineral salts requisite for their healthy development." [1]

7. "On account of the largely cartilaginous and imperfectly knit state of its bones, it is cruel to encourage a young child to walk beyond its strength, and may lead to 'bow legs' or other permanent distortions. . . . The best rule is to let a healthy child use its limbs when it feels inclined, but not by praise or blame to incite it to efforts which are beyond its age, and so sacrifice its healthy growth to the vanity of parent or nurse." [1]

8. "No injury to the joint should be neglected. Inflammation, when once started there, is often difficult to check and runs on, in a chronic way, until the synovial surfaces are destroyed, and the bones perhaps grow together, rendering the joint permanently stiff." [1]

9. "In the red marrow of certain bones is the so-called *hematopoietic* (corpuscle-forming) tissue where red corpuscles are constantly being formed." [1]

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[1] Martin, *Human Body*.

No. 132.

DEVELOPMENT OF THE CHICKEN EMBRYO

Materials. — An incubator and about fifteen eggs, or better, a sitting hen with as many eggs as she can comfortably cover; dissecting scissors with short blade, or manicuring scissors; saucer.

Method. — Provide a nest for the hen in a box, filled with straw, excelsior, etc., and place it in a quiet, darkened place. Wire screen may be placed over the top of the box for a day or so, until the hen has become accustomed to her surroundings, and is well "settled." It is better to pay more for eggs guaranteed to be fertile, for "store" eggs are apt to prove a disappointment. Open an egg every day for the first week, and every other day thereafter. For the first few days, do not break the egg, but merely make a small hole in the shell, and inserting just the points of the scissors blades, cut out a round hole the size of a quarter dollar.

From the first there will be evident a reddish round spot (the blastoderm), from which veins radiate out to the white of the egg, extending farther and farther from day to day. The embryo chicken will appear first as a tiny white spot (the area pellucida) inside the blastoderm. The area pellucida becomes pear-shaped, with the primitive streak (which is the elementary spinal cord) showing. Within 32 hr. the heart will be plainly seen beating inside the embryo. The heart will be about the size of a pin-point, and red; it will be visible as the blood collects in it and is pumped out. It is best to open each egg as the class assembles, but a heart was kept beating for several hours in a physiological salt solution (7 or 8 g. per liter or 1000 c. c.) which was maintained at about 98° F. After a few days the heart is no longer visible, because of the further development of the embryo. Flecks of blood, or blood islands begin to form soon after incubation begins, and these finally unite into blood vessels. Limb buds are seen in about 4 days. The big black spots which shortly appear are the eyes. Movement is evident in the embryo between the sixth and eighth day.

After the first 5 days, it is best to break the egg into the saucer, in order to see the embryo better. Feathers appear in about a week, in the form of small scale-like specks upon the embryo.

It is well to let the students keep individual records of the development from day to day, letting them take notes from their own observations at the time each egg is opened; if they trust to memory, the results will be very unsatisfactory. It is better to have a hen than an incubator, because it gives so much better opportunity for developing the proper attitude towards pets, and an interest in them. You can let different members of the class assist you when you take the hen off the nest every morning for food and water. The students will be interested to see that after a few days the hen will return to her nest of her own accord, and frequently without eating or drinking. The nest should be kept very clean. If an incubator is used, the eggs must be turned every morning, and from about eight days before the eggs hatch, must be sprinkled daily with water.

Answers. — 1. To serve as food for the embryo, during incubation.

2. The yolk is the true egg, which forms the chick.

3. They likewise have an embryo, and the cotyledons furnish the food which is used by the embryo, until the plant gets above ground and can manufacture its own food.

4. To furnish the heat necessary for incubation.

5. She turns the eggs over with her beak and feet.

6. To admit air, which is essential for the development of the embryo.

No. 133.

DEVELOPMENT OF THE FROG EMBRYO

Materials and Method. — In March or early April, you will find frog, toad, and salamander eggs in shallow, fresh-water ponds. The frog eggs will be in clusters of several hundred, inclosed in a gelatinous mass attached to twigs, grass, etc. under water. Collect these eggs in a can or pail, keeping them covered with water, and take along with them a plentiful supply of

the green water plants found in the same pond with the eggs. Place the eggs and water plants in a glass jar or aquarium in a warm, sunny place. Encourage the class to examine the eggs every day, in order to determine as many different changes in the eggs and animals (tadpoles) as they can.

With an elementary class it is not necessary to use a strong microscope, but a hand lens will add interest to the study. Call attention to these facts about the eggs: (1) the black part of the egg above, and the white part (yolk) below; (2) the development of the medullary groove, running along the top of the egg, from one end to the other. This becomes the spinal column; unless the eggs are large, it may not be possible to see it with the naked eye. It is perhaps inadvisable with a beginning class to attempt to follow the cell development within the egg. It is impossible to give any accurate time guide to the study of the development of the tadpole, because this factor depends upon the species. Usually the school year ends before the front legs of the tadpole have developed.

The class will be able to note the following changes in the development from egg to adult: (1) the medullary groove develops in the egg; (2) eggs grow into an oblong body; (3) life is evident — the tadpoles wriggle out of the jelly, and attach themselves to the water weed; (4) in a week or so after the eggs are laid, external gills will be evident from close examination; (5) external gills disappear a few days after this; (6) hind legs develop; (7) front legs develop; (8) tail is absorbed; (9) tadpole leaves the water as a fully developed frog, though small frogs may frequently be found upon land, with the vestiges of their tails still evident. Have the class keep track not only of the changes, but also of the time elapsing between changes.

The development of the toad is very similar to that of the frog, but the eggs are laid in strings instead of a mass. You may get salamander or newt eggs, and these little creatures will prove quite as interesting as the frog or toad, though perhaps not so hardy. The salamander tadpole looks different from the frog tadpole, being more slender, though it is not easy to give specific differences, because of the different species.

The water will probably not need to be changed but fresh water plants should be supplied from time to time.

Answers. — **1.** To protect the eggs from attacks by fishes and other animals which might eat the eggs.

2. The mother frog takes no care of her offspring, while the hen does. The mortality among young frogs is therefore much higher than among young chickens. The care which the higher animals take of their offspring makes it unnecessary for them to be so prolific as the lower animals, which take no care of their offspring.

3. "Practically every egg in a laying hatches, and I have not discovered that any fishes, newts, tadpoles, or aquatic insects eat the eggs. But the tadpoles, from the time they hatch until they leave the water, are preyed upon by water beetles, dragon fly larvæ, newts, and possibly fishes. The entire hatching of a pond may be thus destroyed. Probably ducks feed upon both eggs and tadpoles in great numbers. On leaving the water the little toads are at the mercy of ducks, hens, and many insectivorous birds. Crows and snakes, and many species of hawks and owls feed upon the adults. In addition to those destroyed by natural enemies, many are killed by wheels of vehicles and lawn mowers, and many more are trodden under foot and burned in rubbish."[1] Since man eats so many frogs' legs, he may be classed as an enemy of the frog.

4. See Answers 1 and 2, above. Toads secrete an irritating substance from their skins which protects them; different members of the family, such as tree frogs, are able to change color, so as to blend with the background and be almost invisible; similarly the common toad and frog, when on dirt and gravel, look so much like the background as to be scarcely distinguishable.

5. The amphibia (animals which though air-breathing, except during their development into adults, spend much of their lives under water) number about a thousand species, some of the commoner ones being frog, toad, tree frog, salamander, mud-puppy, etc.

[1] Hodge, *Nature Study and Life.*

6. The lower part of the egg is the yolk and supplies the embryo with food. Some of this yolk, remaining in the alimentary canal, supplies the tadpole for a few days after it has wriggled out of the egg membrane.

7. It sucks off tiny algæ and water plants found on the surfaces of stones and plants.

8. Insects, slugs, cutworms, sometimes birds, etc.

9. None of the species is known to be harmful.

10. All the members of the family are more or less useful because of the insects they devour, a toad being particularly valuable in the garden. Frogs' legs are esteemed a delicacy as food.

11. Warts are not produced from handling frogs and toads. This is a senseless superstition.

No. 134.

DEVELOPMENT OF THE FLY EMBRYO

Materials. — Can full of fresh cow manure or horse manure; a stale meat bone; a dish of cooked cabbage; large box in which to place all the above, after the fly eggs are deposited; screen or mosquito netting.

Method. — Place the various materials in which the flies are to lay their eggs in different windows where flies are apt to be, or some distance apart out-of-doors, to insure that each material will be "blown." After the eggs are deposited (they will be in little piles of creamy, pointed eggs), place the manure, bone, and cabbage in the box, and after placing the screen or netting over the top, set the box in a sunny window. The eggs hatch into maggots, or larvæ, within a few hours, and these feed upon the material upon which the eggs were deposited, for about five days, during which time they moult twice. The larva now develops into the brown pupa stage, and after lying dormant for about another five days, emerges as an adult fly, but with only rudimentary wings, which develop to full size in a short time. The students will be interested in this final process. The purpose of using the above ma-

terials is to show the students a few of the many different kinds of materials in which flies breed. Emphasize the fact that flies will develop in almost any decaying animal or vegetable matter or refuse.

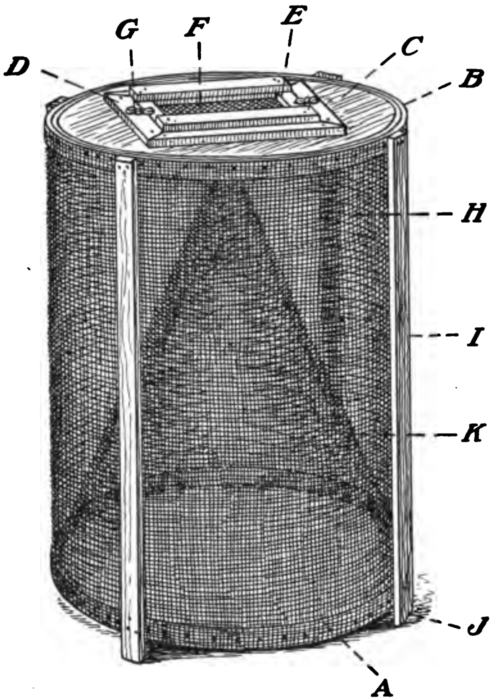

FIG. 107 (T). CONICAL HOOP FLYTRAP.

A, Hoops forming frame at bottom; *B*, Hoops forming frame at top; *C*, Top of trap made of barrel head; *D*, Strips around door; *E*, Door frame; *F*, Screen on door; *G*, Button holding door; *H*, Screen on outside of trap; *I*, Strip on side of trap between hoops; *J*, Tip of the strip projecting to form leg; *K*, Cone.

Set the trap over bait upon the ground. Flies rising from the bait pass through the hole at the top of the cone into the trap.

The fly question is surely one which should be handled "without gloves," and no feeling of delicacy should prevent a teacher from doing his duty in pointing out the real dangers from the fly. Don't hesitate to "call a spade a spade," for only by giving the bare, disgusting facts can the truth really be brought home to the students, in such a way that they will realize the necessity for action against the fly.

The questions are given in the Discussion with the hope that they may prove suggestively helpful as topics to be looked up.

Answers. — **1.** "As the fly passes from the places where it

breeds to our houses, and possibly to the dinner table, it carries all sorts of filth germs on its feet and body, and among them there may be disease germs, too. . . . In the Spanish-American War, about one out of every five of our volunteer soldiers had typhoid fever, and it was found that the fly was one of the principal agents in spreading the disease. In Jacksonville, Florida, flies used to cause a great deal of typhoid, until a campaign for the screening of outside closets reduced the typhoid death rate of the city to less than one fourth of what it had been."[1] "In the adult stage the flies feed upon filth of all sorts, and if they alight on the excretions of typhoid patients they are very likely to carry on their feet and mouth parts the germs of the disease, and so when they come into the house, they may infect milk and other food. Flies also carry germs of other diseases such as cholera, dysentery, and tuberculosis."[2]

2. "By preventing their breeding, by trapping them, and by keeping them away from human discharges and from food."[1]

It is most important to eliminate the breeding places of the fly; swatting only "gets" one now and then, while the other method will eliminate millions; also, one fly killed in the early part of the season may mean the elimination of billions of flies which would develop from the eggs of this single female during the season. ". . . it has been estimated that a single fly may have 5,598,720,000 descendants in a single season if each fly were to deposit but one batch of eggs. In reality, however, a fly deposits four batches in one season."[2]

3. The tiny fruit fly and the stable fly are common. The former prefers to breed in human feces, and is so small as to be able to enter through the meshes of screens. The stable fly is believed by some authorities to be responsible for the spread of infantile paralysis.

4. Keep the outside toilets so tightly closed that no flies can enter to breed. For the stable manure, make a box which can be closed tightly. As the manure accumulates, spread it in a thin layer over the ground, where it will act as a fertilizer, and where the sunshine will soon dry the manure. Flies

[1] Winslow, *Healthy Living*. [2] Peabody and Hunt, *Elementary Biology*.

cannot develop in dry manure. Keep the garbage can tightly covered. Keep the stables and premises clean, and free from refuse.

No. 135.

DEVELOPMENT OF THE MOSQUITO EMBRYO

Materials and Method. — The eggs of the mosquito may be found in stagnant water, in ponds, rain barrels, tin cans, etc. The eggs of the culex, or common house mosquito, float upon the surface in the form of a " raft " which looks like a fleck of soot. You will not be able to distinguish with the naked eye the individual cartridge-shaped eggs, from two hundred to four hundred of which compose these rafts. The anopheles, or malarial mosquito, lays larger eggs, singly. Place the eggs in a glass jar or aquarium in a warm, sunny place; culex eggs hatch into larvæ or wrigglers in a day or less. In about a week the mosquito enters the third stage, the pupa, and in about another week the pupa changes into the adult form. April or May is the best time of the school year in which to study the mosquito. Require the class to take notes upon the development from day to day, and to tell the number of days elapsing between the important stages of development.

Answers. — **1.** To breathe.

2. Larva: through a tube situated in the eighth segment of the abdomen; pupa: through a pair of tubes on the back of the thorax.

3. Rapidity of growth necessitates the frequent shedding.

4. During the larval and pupal stages, when these insects come to the surface of water to breathe. A thin film of kerosene will prevent their being able to get their breathing tubes into the air. You can try this oil method of extermination, as an additional demonstration, using some of the larvæ and pupæ in separate vessels.

5. Larvæ feed upon microscopic animals and plants which infest stagnant water. During the pupal stage, the mosquito, although active, eats nothing. The male adult mosquito

eats fruit juices or nothing, during the short time he lives; the female when she is maturing and ripening the eggs eats blood, which she sucks from living animals; at other times she lives on fruit and vegetable juices.

6. The culex is merely a needless nuisance; the female anopheles is a serious menace. In biting a person who has malaria, the anopheles takes into her body the protozoa (a low order of animal) which produce malaria; and the protozoa will then be injected into

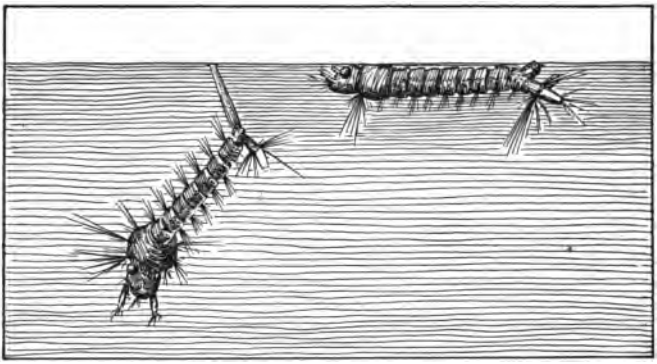

FIG. 108 (T).[1]

Resting position of the larvæ of the common mosquito, Culex (left), and the malarial mosquito, Anopheles (right).

the next persons bitten by the mosquito. The stegomyia is perhaps more undesirable than the anopheles, since she in the same way propagates yellow fever, a very deadly disease.

7. The males and most of the females live but a week or so.

8. If the females are developed in the late autumn, they often seek protected spots, where they remain until spring when they lay eggs in stagnant pools formed by the early rains.

9. The anopheles larvæ breathe in a position almost parallel with the water surface, while the culex assume more nearly a perpendicular position. (See Fig. 108.) The anopheles adult rests "standing on her head" with her hind legs at right angles to her body; the culex rests with her body parallel to

[1] Fig. 108 and Fig. 109 are redrawn from *The Mosquito Nuisance*, by W. Lyman Underwood.

the surface upon which she has lighted, and with her hind pair of legs above her back. (See Fig. 109.)

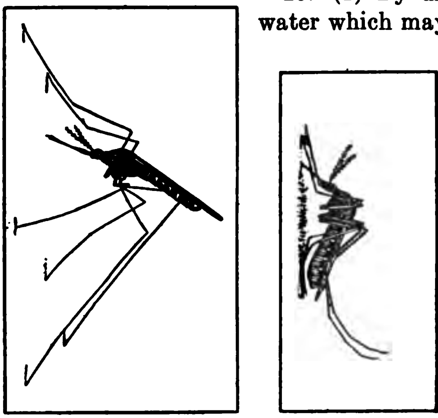

Fig. 109 (T).

Resting position of common mosquito, Culex (right), and malarial mosquito, Anopheles (left).

10. (1) By draining all the stagnant water which may be in old cans, bottles, etc., and from swamps, wherever possible; (2) by introducing small fishes into the water where mosquitoes breed; (3) by pouring a thin film of kerosene over all undrainable ponds of stagnant water. If this is done conscientiously for two or three weeks, the mosquitoes will be practically exterminated. The mosquito is usually found only a short distance from the breeding place, as it is a very weak flier. It flies only ten or twelve feet above ground, and for a distance of only a block or two unless carried by the wind, which may take it as far as half a mile.

No. 136. VITAL CAPACITY OF THE LUNGS

Materials. — Pan of water; two half-gallon fruit jars; 1000 c. c. graduate (preferably, though a smaller one will do); rubber tubing 2 ft. long, fitted with glass tube at each end; glass plate.

Method. — First explain that by *vital capacity* is meant the greatest amount of air which *can* be taken in, or inspired, after all the air which *can* be expired has been forced out of the lungs. Also explain that the *tidal air* is the amount taken into, and expired from, the lungs in an *ordinary* inspiration. Fill both jars

full of water and invert them full in the pan of water. Select some one from the class as a "test." Request him first to exhale all the air he can and then to inhale as much as possible and immediately to take the glass tube in his mouth and blow the air out under the edge of one of the inverted jars. The glass tube in the other end of the rubber tubing prevents the weight of the jar from obstructing the free passage of air. The normal child will probably have a vital capacity greater than half a gallon.

As soon as the first jar is full of air, let the student hold his breath long enough to transfer the tube to the second jar, then let him empty his lungs as nearly as possible. Remove the rubber tubing and refill the first jar for the second test. After a minute or so, during which time the student has resumed normal breathing, let him exhale into the jar only as much air as he *normally* expires. Meanwhile, let another student measure the number of c. c. remaining in the *second* jar, by first placing the glass plate over the mouth of the jar to retain the water in it, and then measuring the number of c.c. remaining, by pouring the water into the graduate. This quantity determined, let him fill the jar from the graduate in order to determine how many c.c. it holds. The difference between twice this quantity, and the amount of water remaining in the second jar after the first exhalation, will be the vital capacity of the student who made the test.

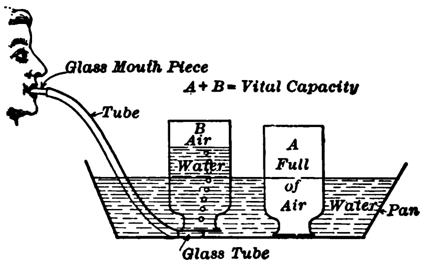

FIG. 110 (T).

In the same way, let another student measure the amount of water remaining in the first jar, after the "test" student expelled the tidal air. The difference between the number of c. c. remaining and the number of c. c. the jar holds, is the tidal air. The per cent of the student's vital capacity used by him in ordinary breathing is, therefore, this last quantity divided by the number of c. c. expelled during the first exhalation.

No. 137. ACTION OF THE DIAPHRAGM

Materials. — Bicycle or auto pump, with the tube removed; touch paper. (See No. 31 on Convection.)

Method. — This experiment is of value only in roughly indicating how the diaphragm works to produce abdominal breathing, and will give no idea of the action of the chest muscles in costal breathing. You may find it advisable to explain that the chest muscles work more like the sides of a bellows in filling and emptying, but this also is but a rude approximation. Hold the bicycle pump upside down with the piston downward. Light the touch paper and hold it near the vent in the bottom of the pump; then slowly and steadily pull down the piston. The smoke currents from the touch paper will be forced into the piston chamber in small quantities, as the capacity of the chamber is increased. Slowly and steadily push the piston up toward the bottom of the tube; the smoke will be forced out of the chamber as the volume is decreased. Repeat the whole process several times to represent breathing, and until the process is thoroughly understood.

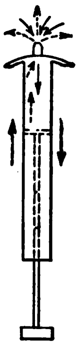

FIG. 111 (T). BICYCLE PUMP.

Solid arrows indicate downward stroke of the piston and the direction of air currents; dotted arrows indicate the upward stroke of the piston and the direction of air currents.

Answers. — It may be well to assign the various questions to be looked up outside of class and reported upon, and give very full discussions of them in class, for the students will probably be able to do little with them unassisted.

1. In violent exercise, more oxygen is used by the body than is normally used, and hence oxygen has to be supplied rapidly to the lungs.

2. The exchange of oxygen and carbon dioxide is made in the lung capillaries by the process of osmosis. (See No. 114.)

3. The diaphragm is a muscular wall between the abdomen and the thorax, the cavity which contains the lungs. When relaxed, the diaphragm extends upward like an inverted saucer

or dome of muscle. When this muscular wall is contracted, the bottom of the "saucer" or the top of the "dome-shaped" muscle becomes flatter, and therefore the lung cavity is made larger. The elastic lung tissues immediately expand to fill this increased volume, making the air in them less dense, whereupon the greater pressure of denser air outside forces air into the lungs until the pressure inside and out is equal. In expiration, the diaphragm muscles relax, and again bow upward, decreasing the volume of the lungs, whereupon the greater pressure inside the lungs forces air out, until an equilibrium of air pressure inside and out is again attained. In inspiration, the ribs and sternum (breast bone) have to be raised, in order to increase the cavity inside; in expiration the muscles are relaxed, whereupon the weight of the ribs and sternum causes these bones to sink, decreasing the cavity. The reason for inrush and outrush of air is the same as previously explained. Both kinds of breathing, abdominal and costal, go on simultaneously (this is the reason why neither the pump nor the bellows alone serves to illustrate breathing).

4. *Residual air* is the air remaining in the lungs after the most violent possible expiration. *Supplemental air* is that which, in addition to the residual air, remains in the lungs after an *ordinary* expiration. The *stationary air* is the residual plus the supplemental. The *complemental air* is that which can be added to the tidal air by a forced inspiration. From these definitions it will be seen that the vital capacity is the sum of the tidal, supplemental, and complemental air together.

5. Abdominal. But neither rib breathing nor abdominal breathing should predominate; neither has any especial advantage over the other which would make it comparable with a combination of both. The breathing movements should exercise all portions of the lungs. Men have a tendency to abdominal breathing, women to rib breathing. Each should give particular attention to developing the other type of breathing.

6. Tight corseting and tight cinching of a belt impede the action of the diaphragm, leading to shortness of breath and incapacity for muscular exertion, and in extreme cases some of the

vital organs, as for instance the liver and kidneys, are injured. Since wearing tight corsets impedes the action of the diaphragm, rib breathing is apt to predominate as a result. This is the most injurious effect, not only because the lower portion of the lungs is poorly ventilated, but also because unused tissues are most liable to disease. Tuberculosis usually begins in an unused portion of the lungs.

No. 138. BLOOD CIRCULATION

The class will be delighted with these three following experiments, and if carefully guided, will get a considerable amount of accurate information, not easily mastered from books alone. Texts should, however, be freely consulted in regard not only to parts of the experiments themselves, but especially in connection with the Discussion, in the study of which it may be well to assign the different questions to be looked up outside of class and reported upon fully in class.

Materials. — A living frog or tadpole (the tadpole is perhaps more easily obtained, and is very satisfactory); a little ether or chloroform, if you use the frog; a little absorbent cotton, if you use the tadpole; compound microscope.

Method. — If the frog is used, put it under the influence of ether or chloroform, by placing it in a pail or bottle and adding enough of the anæsthetic to anæsthetize the animal. If the tadpole is used, moisten a little wisp of the absorbent cotton and wrap the body of the tadpole in it, leaving the tail free. Place the tadpole upon a glass slide, and focus the tail under the low power of the microscope No anæsthetic is needed, though the tadpole may flip its tail occasionally, requiring a refocusing of the microscope. If the frog is used, focus the web of the hind foot under the low-power lens in the same way. You will be able to show the class the rapid *pulsing* of the blood in the arteries, the slow "single file" movement of the corpuscles through the capillaries, and the steady, rapid movement through

the veins. You may have to make several focusings of different portions of the tadpole tail or frog foot before you can show the class the flow of blood through all three. It is doubtful whether you will be able to follow the flow of blood from artery to capillaries to veins; you will probably have to find and show each, more or less separately.

No. 139. STUDY OF PULSE

Materials. — Watch or clock; the class.

Method. — Let one member of the class act as timekeeper, and tell the rest to find their pulses, either in the left wrist with the right hand or in front of the ear, or in the pit of the neck. Feel the pulse with the *tips* of the fingers. When all have located their pulses, let the timekeeper say, "Ready, count," whereupon each will count his pulse until the timekeeper says, "Stop," after a minute. Find the average pulse rate of the oldest boys and of the youngest boys, by adding the number of beats of the boys in each group and dividing by the number of boys in that particular group. Similarly, find the average pulse rate for the oldest girls and the youngest girls in the class. The pulse rates will probably vary between sixty and ninety. The pulse rate of women is three to five beats more than that of men. Within the school ages, the older children will in general have slower pulse rate than the younger ones. Unless your class is a large one, the above-mentioned differences may not show, because the taller pupils will have slower pulse rates than the shorter ones, and because the health of the individual makes a difference. It may therefore be advisable to select individual cases to demonstrate the above facts.

It will be interesting to compare normal pulse rates of different students with the pulse rates of the same students after they have run around the block.

No. 140. STUDY OF THE HUMAN BLOOD

Materials. — Compound microscope; slide; cover glass; needle; rubber band; a little alcohol.

Method. — Wash the finger, then dip the end in alcohol to kill any germs which may be on the finger. Sterilize the needle by holding it for a moment in a flame. Bind the rubber band tightly around the clean finger near the end, then quickly puncture the skin with the needle, and place the drop of blood which collects, upon the glass slide. Place the cover glass over the drop of blood and focus under the high-power lens of the microscope. The red corpuscles, tiny disks usually together in "stacks," will be visible in great numbers, with here and there a white corpuscle (about one to every three hundred red) a little larger, single, and of irregular outline. The students will be able to distinguish these two kinds of corpuscles and the plasma, or liquid of the blood, in which the corpuscles float. It is doubtful whether any member of the class will see individual motion of the white corpuscles.

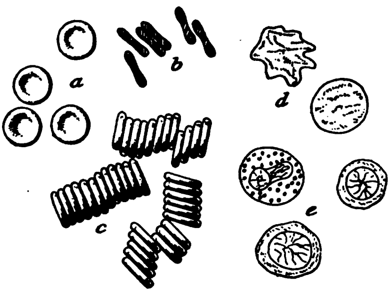

FIG. 112 (T).

a, Red corpuscles, surface view; *b*, Red corpuscles, cross section; *c*, Red corpuscles, edge view; *d*, White corpuscles, nucleus not seen; *e*, White corpuscles, nucleus at center of each.

Answers. — **1.** The heart forces the blood into the arteries which expand sharply and then contract to their former shape more slowly than they expand. The contraction of the artery in one place causes an expansion further along as the blood is forced on. Thus a wave of pressure passes along the arteries with each beat of the heart. These changes in pressure are called the pulse.

2. When the blood is pumped out by the heart, the thick walls of the arteries are distended by this increased pressure. As

soon as the pulsation is over, however, the elasticity of the arterial walls causes a contraction, which forces the blood along through the "canals." Muscular movements likewise assist in keeping the blood flowing, by producing intermittent pressures upon the blood canals; the valves in the veins keep it from flowing backward, and the decreased pressure which occurs periodically in the auricles following a contraction, as well as the varying pressures in the thoracic cavity, tends to empty veins.

3. By the time the blood reaches the capillaries, it has had the number of channels increased until the speed of flow in each is naturally decreased; the blood is more "spread out." But when the blood flows again into the veins from the capillaries, the merging of so many channels into one produces a corresponding quickening of current, though the pulsation is no longer evident, having been eliminated by the passage of the blood through the many channels of the capillaries.

4. The capillaries are the most important portion of the blood system. They form a network of fine tubes, which communicate freely with one another and bring blood to all cells of the body, especially those near the surface and in the lungs. Through the thin walls of the capillaries, those osmotic exchanges of material occur which enable each cell to take from the blood the food and oxygen it needs, and to give off to the blood the carbon dioxide it has formed by oxidation.

5. The phagocytes are certain of the white corpuscles or leucocytes, supposed to have the power of individual amœboid motion (like an amœba, see Fig. 105, No. 126), enabling them to pass through even the walls of the blood canals in search of pathogenic bacteria which they engulf and devour. If the bacteria are too numerous, however, they may emit enough poison to kill the phagocytes. Pus is white because it is filled with the bodies of dead phagocytes, and the bacteria and their products.

6. The hæmoglobin of the red corpuscle unites in a loose chemical combination with oxygen, and the oxygen is in this way picked up in the lungs and carried along in the blood,

whenever the oxygen is less concentrated in the surrounding media than in the red corpuscle. The red corpuscles as they return to the lungs, also remove from the tissues some of the carbon dioxide, by practically the same process. The red corpuscles are manufactured in the hematopoietic tissue of the red marrow of certain bones.

7. To carry the various foodstuffs which nourish the body cells.

8. Dirty yellow, due to the proteid material, hæmoglobin, which contains a considerable quantity of iron.

9. See Answer 5 above.

10. Frog corpuscles are more pointed than human corpuscles are; the human corpuscle is concave on both sides, while the frog corpuscle is convex in the middle. It is not likely that the students will have noticed this last comparison.

11. If a vein is severed, causing a reverse in direction of blood flow, tiny valves in the vein, which permit the flow only toward the heart, close, shutting off the blood supply from one direction. Clotting tends to stop bleeding.

12. See explanation and Fig. 114 in the Discussion of No. 146.

No. 141. BASIDITY OF SALIVA

The two following experiments upon saliva are the only attempts made in this book to give any demonstrations to illustrate the digestive processes, because, while such experiments are possible and fairly satisfactory, they require such careful performances as to make them impractical and impracticable for the ordinary elementary course.

Materials. — Strips of red and blue litmus paper.

Method. — Place a strip each of red and blue litmus paper upon the tongues of two or more students. After a few moments, remove them. The red strip will be found to have changed slightly to blue, indicating that the saliva is basic or alkaline. This experiment should be preceded by the one on acids, bases, and salts, No. 78.

No. 142. ACTION OF SALIVA IN CHANGING STARCH TO GRAPE SUGAR

Materials. — Burner; test tube; a cubic centimeter or so of saliva and another of smooth starch paste made by mixing a pinch of cooking starch with cold water; A and B Fehling solutions (see No. 110, on Food Tests).

Method. — Place the starch paste and saliva in the test tube, and pass the test tube through the flame of the burner once or twice until the liquid is about as warm as one's mouth. Test with your elbow on the outside of the tube after each passage through the flame, and do not allow the contents of the tube to become too warm. Let the tube stand for five minutes, and then make the Fehling test for grape sugar in the same way as indicated in No. 110 on Food Tests. The orange color will indicate grape sugar in the test tube.

Answers. — **1.** (1) To allow as much surface as possible upon which the digestive secretions can act; (2) to digest as much of the starch as possible in the mouth before the food is swallowed. When the saliva reaches the stomach, the action of the salivary ferment, ptyalin, is soon stopped by the presence of acid, which contains the ferments, rennin and pepsin.

2. Parotid, under the ear; sublingual, under the tongue; submaxillary, under the jaw.

3. The enzyme or digestive ferment, ptyalin.

4. Diastase.

No. 143. EFFECT OF NICOTINE UPON LIVING ANIMALS

Materials. — Several living tadpoles or a minnow or goldfish in a battery jar or aquarium full of water; a small handful of fine-cut chewing or smoking tobacco; square of cheesecloth; burner; beaker.

Method. — Make a tobacco infusion by boiling a small handful of tobacco in a cupful of water; strain the infusion through

the cheesecloth, and when the liquor is cool, put the minnow or tadpole into it. The tadpole or minnow will soon die in the infusion. Experiments have been made to show that the smoke of six cigarettes, when blown into a jar of water containing a healthy goldfish, has been sufficient to kill the fish.

No. 144. EFFECT OF ALCOHOL UPON ALBUMEN

Materials. — Raw white of egg; alcohol; test tube.

Method. — Pour the test tube a third full of the egg albumen, and add a little alcohol. Wherever the alcohol touches the albumen, the latter coagulates. Add equal parts of alcohol and egg albumen. Shake the test tube. The albumen will form a hard lump.

Answers. — So much has been written, and so many valuable articles are to be found in various texts covering the following questions, that no attempt is made to give more than very brief answers. It is suggested that the various questions be assigned to be looked up by different students outside of class, and reported upon fully in class. The lessons conveyed with these experiments as a basis will probably be more effective if the discussion is kept as *scientific* as possible, with the various *moral* aspects ignored.

1. A few drops of pure nicotine will kill a man. It is reasonable to infer that even the small quantities taken into the system in the use of tobacco cannot fail ultimately, in the majority of cases, to do serious harm to the bodily organs.

2. "The frequent use of cigars or cigarettes by the young seriously affects the quality of the blood. The red blood corpuscles are not fully developed and charged with their normal supply of life-giving oxygen. This causes paleness of the skin, often noticed in the face of the young smoker. Palpitation of the heart is also a common result, followed by permanent weakness, so that the whole system is enfeebled, and mental vigor is impaired as well as physical strength." [1]

3. The nicotine in the tobacco water kills the insects.

[1] Macy, *Physiology*.

4. Smoking has the effect of retarding the heart beat and weakening the activity of the red corpuscles (*i.e.*, their power to carry oxygen). "When smokers have 'poor wind,' it is because their hearts cannot pump the blood fast enough to supply the oxygen needed by their muscles, and the lungs have to do extra work to make good the deficiency."[1] Tobacco smoke, especially that of cigarettes, often causes pharyngitis, and produces an irritation in the bronchi and lungs. The smoke of a cigarette, being milder than the smoke from a pipe or a cigar, is much more likely to be inhaled.

5. When alcohol is taken into the body, the cutaneous blood vessels are dilated, permitting more blood to reach the surface of the body, and thus producing a temporary feeling of warmth. The true effect, however, is to increase the radiation of heat from the blood and to *lower the body temperature.* If the amount of alcohol consumed is considerable, and if its effects are combined with those of extreme cold, death frequently results, since the surface of the body is warmed at the expense of the internal organs.

6. White of egg very closely approximates in composition the protoplasm of living animal cells.

7. The alcohol absorbs the water of the albumen, causing the coagulation.

8. The answers to this question are too voluminous to admit of careful treatment in a text of this sort. See any standard text in physiology or biology.

9. The alcohol user and the cigarette smoker are discriminated against, because the employer has *learned* that the cigarette and alcohol user is less dependable and efficient than the abstainer. In many cases employers will not hire men who are known to be users of alcohol and tobacco. Insurance companies will not knowingly insure a chronic alcohol-user, because they have *learned* that he is not a good "risk." These judgments are not due merely to prejudice, but are the result of exhaustive tests covering a period of many years. It may be well to emphasize this last statement.

10. Experiments conducted by Dr. Hodge in Worcester, Mass.,

[1] Winslow, *Healthy Living.*

showed that one effect of giving alcohol to dogs was to increase the percentage of death and deformity among their offspring. Though the question is still unsettled, the consensus of authoritative opinion seems to be that where both parents are alcoholic, the children are rarely normal; they may be epileptic, neurotic, or even insane, and often are afflicted with nervous diseases of various kinds.

No. 145. PATENT MEDICINES

This experiment cannot fail to produce some good results by interesting the students in patent medicine frauds, thus aiding the crusade against this great evil. This experiment is based entirely upon material contained in *The Great American Fraud* [1] and, for the most part, the questions are answered only with page references to this book. The questions are only a few of the legion of similar vital questions which may be asked and answered from this and similar books obtainable at slight cost from the American Medical Association.

Answers. — **1, 2,** and **3.** Pages 38, 39, 40, 125, 126, etc.

4. Pages 40, 41, 80, 129, etc.

5. Page 46.

6. Page 16.

7. Page 125.

8. Page 53.

9. They fail to cure the diseases they advertise to cure; they contain injurious drugs, in many cases, which result in harm, the drug habit, or death; they keep the sufferer from consulting competent medical advice until it is too late.

[1] Published by American Medical Association, 535 North Dearborn Street, Chicago. Price, paper, twenty-five cents; cloth, fifty cents.

No. 146. FIRST AID

Materials. — Penholder; clean handkerchief; stick, such as a thick kindling.

Method. — It is of course impossible to give any extensive directions regarding demonstrations, and therefore only the tourniquet and the method of removing particles from the eye are included as the experiment. "If the blood comes from a wound in jets or spurts, an artery is bleeding and the result may be serious if the flow is not checked. . . . Put firm pressure close to the bleeding part, between the wound and the heart. In case the wound is in the arm or the leg, the pressure is best applied by tying a knot in the center of a folded handkerchief, and laying this knot over the artery. Tie it loosely around the limb, but with a good knot. Place a stick under the bandage and twist it round and round until the bandage is tight enough to stop bleeding."[1] (See Fig. 113.)

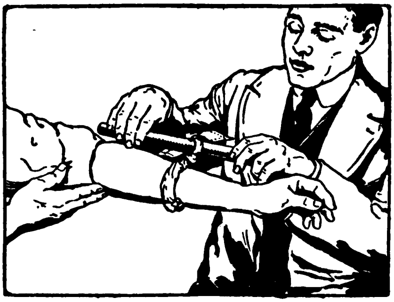

Fig. 113 (T).

The following information should be given along with the demonstration for removing a particle such as cinder or dust from the eye: " . . . The eye should not be rubbed, for rubbing only makes matters worse. If the particle can be seen on the eyeball, it may be removed with the corner of a clean, soft handkerchief. A speck on the lower lid often becomes visible, so that it may be removed, if the lid is pulled down with the finger. Sometimes, if the eye is kept closed for a few minutes, the tears, which flow whenever the eye is hurt, will wash the speck out where it may be seen and removed. Blowing the nose may also help. Sometimes a particle on the upper lid may

[1] Winslow, *Healthy Living*.

be removed by taking hold of the lashes of the upper lid, and pulling it down over the edge of the lower lid two or three times while the patient looks downward. If this does not dislodge the speck, it must be looked for on the upper lid by taking hold of the eyelashes and rolling the eyelid back over some small object, such as the small end of a penholder. The speck may then often be seen clinging to the under side of the lid. (See Fig. 114.) If the object cannot be removed in this way, a doctor should be consulted, for a sharp particle may in time work in and do serious harm."[1]

FIG. 114 (T).

Answers. — **1.** Keep cool and send for a doctor.

2. "Slight cuts and scratches should be washed free from dirt, then dried with clean gauze, and painted with tincture of iodine."[1]

3. Because of the danger of infection. "A doctor should be consulted about even the slightest scratch if, after a few days, it is red, hot, or painful; and a deep wound, particularly if produced by a rusty nail or other dirty object, should always receive prompt medical attention. . . . Remember that germs get into a wound, not from the air, but from dirty things that touch it. A scratch or cut should never be touched with anything but sterilized surgeons' gauze, and above all should never be picked with the fingers."[1]

4. Ice in a cloth or simply a cloth dampened in cold water will serve to drive the blood away. This treatment should be kept up at intervals for twelve hours, for sprains. "In old and enfeebled patients, hot wet cloths are better. The injured part should be placed as high as possible, so as to keep the blood out of it."[1]

5. The best treatment for serious burns is the open-air treatment or fanning, which is ideal if an electric fan can be kept blowing upon the burn. A ten per cent solution of picric acid

[1] Winslow, *Healthy Living.*

(obtainable at any drug store) is probably next best, but it is objectionable because it is a poison and it stains everything with which it comes in contact. A doctor should be called to administer morphine to the patient to relieve the shock and the pain.

6. " A few drops of castor oil or sweet oil may be dropped in; this will usually wash the insect out. If anything gets into the ear, it is safest to send for the doctor at once, as an attempt to remove anything from the ear with pointed objects may be dangerous." [1]

These are only a few of dozens of similar questions which may be asked, the answers to be looked up and reported upon. There can be no experiment more practical than such as these, and the class will be enthusiastic over a chance to learn what to do in emergencies.

[1] Winslow, *Healthy Living*.

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Italics indicate a fully outlined or suggested experiment upon the topic indicated. For example, "*Caking of soil*, 124," means that an experiment upon this topic is fully described on page 124 of the TEACHER'S MANUAL.

Black type numerals refer to Answer numbers in the Discussions. For example, "171, **3**," means page 171, Answer **3**. It is expected that all such references will be compared with the corresponding Questions in the STUDENT'S MANUAL.

An asterisk (*) indicates a Figure. For example, "Anther,* 166," indicates that a Figure showing what an anther is, is shown on page 166. Figure references are usually not indicated when they occur on a page where there is other reference to the topic illustrated in the Figure.

A few special references to the STUDENT'S MANUAL are indicated by S. For example, "Anti-clockwise, defined, S, 2, **2**," means that the definition of "anti-clockwise" will be found under Question 2, page 2 of the STUDENT'S MANUAL.